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ELECTRICAL WORLD

75th Anniversary Issue

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ELECTRIC POWER INDUSTRY

Past, Present and Future

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Our Anniversary Objective

ELECTRICAL WORLD now is seventy-five wonderful years old. Such a venerable age is not important in journalism, except as it gives one the experience upon which sound judgments are based. Yet, combine this with an accepted objectivity, with adequate facilities, with a knowledge of sources—plus traditionally unseeking cooperation from those who are asked to help—and no task is fearsome to contemplate.

Thus it is that we, as brashly as our youth would allow, set out to supply in this issue what men in all branches of the electrical industry have long discussed as necessary: A step-by-step examination of the development of modern electric systems and apparatus. We visualized this as a comprehensive study covering the evolution of energy generation, distribution, and utilization, with attention to some of the social, economic, and political influences in our industry.

This is work for which an industrial publication is well suited. For, as the late James H. McGraw wrote just twenty-five years ago, "Nine-tenths of education springs from the contact of mind with mind—the other tenth a man may get for himself if his own mind is fertile enough. Mental contact may come through either the written or the spoken word. In our day it is the written word that plays the lion's share, and a technical paper that proves unable to teach not only the freshman and the industrial neophyte but, on occasion, the master scientist, the veteran engineer, and the industrial leader, is not fulfilling its mission. To do this the editor does not need to know more than all others; he needs the instinct to recognize achievements in embryo, the insight to divine where knowledge lies, and the tact, where necessary, to coax its possessor into utterance."

We confidently believe some of the sections in this issue, particularly those on engineering, constitute a more authoritative, terse, and lucid review of the circumstances which stimulated technical advances than can be found in such compact form anywhere else. Young men in the industry can here get a fund of information and a perspective which otherwise would take years. Senior operating men and management officials can get a better appreciation of those parts of the system which they have inherited and may have been too busy to evaluate. This "refresher" may make it possible for them to plan better the replacement of obsolete apparatus and practice not only with what is new, but with what will be newer still.

We gratefully acknowledge the tremendous help of those contributing editors who are listed in the various sections. Obviously, without them and their cooperation this issue could not have been written.

And we reaffirm our faith in the industry with which we have been privileged to live and grow. We expect our enthusiasm to be even greater, and our vision even more exalted, as we continue our work of recording and interpreting all that goes on in the field, day by day.

Technical Reporter and Sponsor of Development

In its 75 years Electrical World has played a leading and sometimes determining part in industry progress

A YOUNG Western Union telegraph operator named W. J. Johnston and a few of his friends started a little gossip sheet in 1874 for circulation among their fellow key pounders in New York City. A man named Tom Edison contributed a few pieces to the *Operator*, as the paper was called, and because of the considerable attention thus gained, the amateur publishers and editors found they had a business in their hands. They hardly knew what to do with it. Then, in 1876, Johnston's boss offered him the choice of being fired from his job or giving up his interest in the paper. He chose publishing, and became sole owner. Under his management the magazine prospered, changed its name to *Operator* and *Electrical World* in 1883, and soon after became simply ELECTRICAL WORLD.

The electrical industry was in its first great expansion period; new inventions and developments came thick and fast. In the period of Johnston's ownership, 1876 to 1898, the office of ELECTRICAL WORLD was a clearing house for electrical inventions, acting as patent examiner and adviser.

From his acquisition of the paper in 1898 until his death in 1947, James H. McGraw gave greatly of his energy and thought to ELECTRICAL WORLD. The words he wrote for its Fiftieth Anniversary issue serve as well today as then to tell its story:

"The paper was forced to grow with its growing field. . . . This necessity has persisted. . . . If it can rightly claim that it has filled its field and discharged its mission, the claim must be based, not on any occasional special feature or brilliant article, but on proof that it has kept step steadily and constantly with the advance of the industry it serves, has neglected none of the regimental divisions of that electrical army, and has been the standard bearer not of a troop but of the whole advancing host."

How ELECTRICAL WORLD has kept step and borne the standard could be the theme of a long recital of developments and events in which it played leading, sometimes determining, parts. Occasionally critical, always friend and advocate, the paper sought early and earnestly to inspire organization and cooperation within the young industry which were to become so essential to its sound yet rapid growth. From before the time that the American Institute of Electrical Engineers was formed in ELECTRICAL WORLD's offices, in 1884, its editors have counselled and often led such activities.

One could point to the crusades for standardization of voltages and frequencies, of apparatus ratings and specifications, and of nomenclature and symbols. Then there was the publication's early support of holding companies ("syndicates", it called them) as the logical solution to the financial and technical problems which beset the thousands of individual operating units; and its later warnings against holding company and financial abuses—warnings which went unheeded until too late. One might also list many articles by now famous men.

There are many specific evidences that the paper continues in its tradition of service. Let us cite a few. Each is an example of how a publication, by editorial suggestion and by selective choice of articles, over a period of time can direct an industry's thinking in the way of progress.

Statistics

The first national statistical report on the central station business was made by the U. S. Census Bureau in 1902. Thereafter, the Census reports appeared at 5-year intervals for 35 years. But 5 years was a long time to wait for new data on a rapidly growing industry. ELECTRICAL WORLD stepped into the breach in 1904 and for about 20 years was the only agency to collect and publish annual statistics on electric utility operations. Then in 1926, the National Electric Light Association organized what is now the statistical department of the Edison Electric Institute. With the cheerful cooperation of the Institute and of the Federal Power Commission, ELECTRICAL WORLD still publishes estimates of the past-year figures each January, combining these with data from other sources and with a survey of new construction and capital expenditures, completed and planned.

Fractional-Horsepower Motors

"With the increasing number of motor-drive household appliances being used, power companies have become apprehensive over the possible effect which the high starting current, poor power factor, and low efficiency of certain types and makes of these motors may have on customers' service conditions."

This 1926 editorial observation of ELECTRICAL WORLD is a comparatively mild paraphrase of the words then being exchanged between utility men and makers of power appliances, particularly washing machines. The magazine urged co-operation of the two factions in solution of the problem and was largely instrumental in formation of a joint committee representing 6 manufacturing and 2 utility trade associations. From the work of this committee there came in 1928 an agreement on motor standards which in the following years greatly improved performance of power appliances from both user and utility standpoints and consequently enlarged the sale and use of them.

System Planning

Up to 30 years ago practically all electricity supply systems "just grew," like Topsy. In an editorial, May 25, 1929, ELECTRICAL WORLD stated the situation in more and staider words, "It is not surprising in an industry where development of apparatus and growth of service have been as rapid as in the electrical field that many existing systems appear to conform to no logical plan of evolution."

Many systems kept on just growing and so continue. But many others began around 1929 to give thought to planning their growth and have profited much thereby. System planning cannot be claimed as an ELECTRICAL WORLD invention, but the magazine was an active and effective proponent of it. The article "Utility System Planning," published May 25, 1929, was the first comprehensive statement on the subject and is a classic.

Rural Line Construction

Cost of building farm service lines was a prevalent topic of discussion at engineering and other industry meetings in the middle '30's. It was frequently charged that habits of thought in design and construction of urban distribution were keeping costs of rural line extensions at an unnecessarily high level. To a certain extent this was true. It was also true that for years past power company engineers had been working hard to develop simplified equipment, structures, and methods to reduce the cost. The situation was confused, to say the least. ELECTRICAL WORLD contributed much to clarification of it.

"Costs and Construction of Farm Lines" is the title of an exhaustive analysis of the electrical and mechanical design features of farm lines, of the factors determining design and of the costs of completed lines. This study, which covered 194 lines of 105 power companies in 37 states, was published February 29, 1936. On August 15, following, there was printed a large collection of pictures and drawings showing construction details. Costs and construction of 86 lines of REA co-operatives were analyzed in the issue

THE "OPERATOR", started in 1874, was "A Journal of Telegraphic, Telephonic & Electrical Science, Literature, News & Progress." In 1883, it became *Electrical World*, "A Journal for Telegraphists, Telephonists, Electricians and Electrical Engineers"

of April 24, 1937. These 3 editorial features put on record the rural line construction practices of the time and served as a useful base for further development.

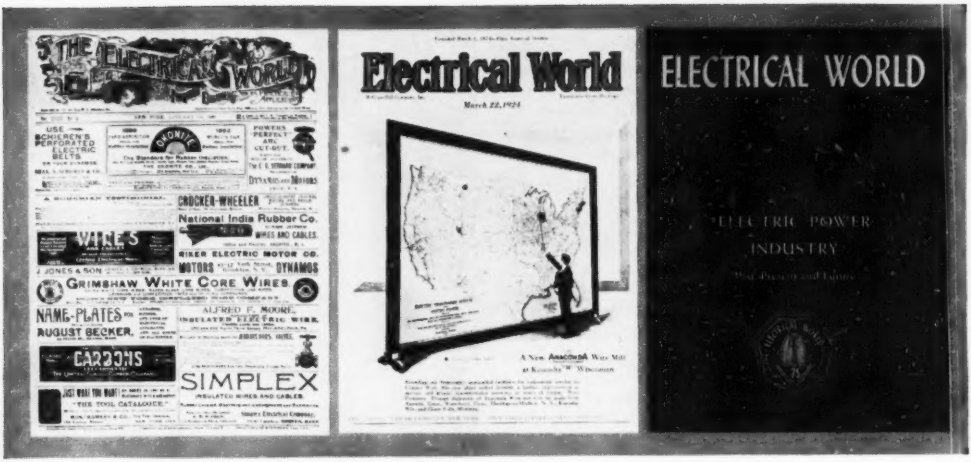
Priorities Problems

During the war priorities were imposed on purchases of many kinds of materials and manufactured goods. To assist utilities in obtaining the necessities required for war-time service, ELECTRICAL WORLD started, September 5, 1942, a series of case studies of priorities problems. The series ran through October 30, 1943, and included 81 specific instances of utilities, manufacturers and government working together to meet urgent needs with the least possible drain on scarce materials. These cases, by example, showed utilities how to go about getting prompt and adequate consideration of their requirements. Additionally, the series included instructions and information on prescribed procedures in applications for priorities orders.

This series was an extraordinarily useful editorial service and was so acknowledged by frequent comments from utility men, who found the published material very effective in facilitating their operations under war-time controls.

Resuperheating

Is it worthwhile to bleed off steam as it passes through the turbine, return it to the boiler for reheating, and then start it on its way again? One says, "Yes"; one says "No." Each is right, no doubt, in the circumstances of his particular case. But what are the circumstances that lead to these opposite conclusions?



ELECTRICAL WORLD'S ANNIVERSARY YEARS—25th in 1899, 50th in 1924, and 75th in 1949

To find the answers to such questions a letter went out to utility heads asking them to have their engineers fill in an accompanying form with the indicated data. And it was a formidable form, too. But because the executives and engineers knew that the resulting published information would be invaluable, they made no moan and cheerfully supplied the data which will soon be published.

Steam Station Cost Survey

"It may be unsafe to prophesy, but the trend is so marked that a future plant may be visualized in which the turbine and the boiler compose one power structure. A turbine placed on top of a boiler, or incorporated with the boiler, with high-pressure stages, intermediate stages, reheating and stage bleeding, offers entrancing possibilities for reducing building dimensions, piping, and investment costs, while giving freedom for a unity of control and operation much to be desired."

Turbines on tops of boilers are not yet to be seen in utility power plants, but certainly the incorporation of turbine and boiler into one power structure, as comprised in the unit-type plant of today, comes close to realization of the editorial prophecy of a quarter of a century ago. The quotation is from the issue that contains ELECTRICAL WORLD's first Steam Station Cost Survey, September 26, 1925. The latest was the fifth, July 3, 1948.

This survey has earned for itself a high place in technical literature. Its data are used in plant design and as references for comparative studies of station performance. It has been drawn on as source material for text books and taken for instruction in college courses.

Lighting Promotion

"Building Load with Light," "Lighting, the Universal Load Builder," "Lighting for Revenue"—No, that's not ELECTRICAL WORLD chiming in on the Planned Lighting Program. That's ELECTRICAL WORLD selling lighting load to the utilities up to 10 years before the Program made its bow.

Distribution Today

Running now in ELECTRICAL WORLD is a series of articles under the general heading of "Distribution Today." The series is intended to (1) examine principles that must guide the adaptations of today's systems to tomorrow's loads, (2) define the more significant problems, and (3) outline the approaches to their solutions.

This is not a new undertaking for ELECTRICAL WORLD. As previously mentioned, distribution has always absorbed a large proportion of editorial attention; hardly an issue but contains one or more articles on transformers, capacitors, substations, networks, fusing, all the components and aspects of the job of putting electricity where it is wanted. The same perception of need for emphasis on distribution that started the present series was the spring of another that ran from July 1940, through 1941 under the heading "Programmed Distribution."

In Conclusion

If space permitted and readers would stand for it, this pointing with pride could be continued page after page. We could be positively lyrical about the studies, surveys, and examples of editorial prescience on rural electrification, transformer and other standardization, house heating, load analysis, public and employee relations, job specification, load building, professional and trade associations. But we must wrap round us the shreds of modesty we are forced to retain and allow our readers to move on to the story of the electric industry, past, present and future, in the following pages. We can't refrain, though, from citing them as examples of ELECTRICAL WORLD's accomplishments.

The Electric Utility Companies

This country leads the world in electricity supply and utilization because business enterprise saw the potentialities and developed them

ELECTRICITY SUPPLY to the people of this country is a little over 80% in the hands of business enterprise. The power companies—so designated in this article to distinguish them from other electricity suppliers which are agencies of, or fostered by, government—have the following proportions in the electric utility national picture: Generation, 80.8% (1948); capacity 80.2% (1948); customers 81.2% (1947). Quantitatively, the power company figures are: Generation, 228.2 billion kwhr; capacity, 45.3 million kw; 31.2 million customers.

Total capitalization of the power companies is nearly $16 billion of which about 49% is in bonds and other long-term debt and 51% in ownership, that is, preferred and common stocks. These securities are widely distributed among institutions, such as savings banks and insurance companies, as well as in holdings of many thousands of individuals. Thus it is that the power companies, although commonly termed "private" utilities, are truly "public" in ownership.

Securing the $16 billion capitalization are nearly $22 billion of combined assets, of which close to $18 billion are in physical plant value. Total operating revenue is about $4.5 billion which, after deduction of operating expenses, results in a gross income of around $900 million. This gross income represents a return of approximately 5% on plant value and 5.6% on capitalization.

The foregoing figures on the financial position of the power companies are estimates, subject to revision when final data for 1948 have been published. But they can not be far out of line as round-figures.

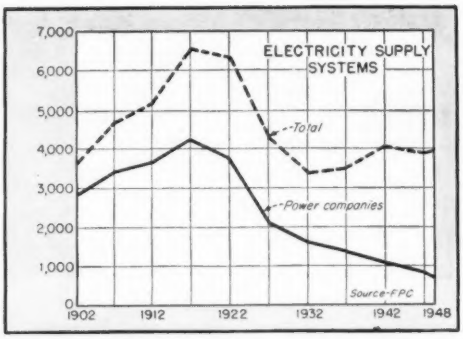
The present vast estate of the power companies had its beginnings in the small, scattered undertakings of highly speculative character that are characteristic of American enterprise scenting opportunity for profit. As the opportunity expanded with time the companies grew rapidly in number. But they remained small because the radius of electricity distribution was short.

The power company business was built on supply of direct current which required metallic connection of generating to utilization equipment. For safety, the circuits had to be of low voltage and consequently the area that could be served from one point of generation was limited. One company served a few blocks of a city, next to it was another. In the larger cities many companies sprang up, each with its own service area and usually in fierce competition with its neighbors as all tried to extend their areas. Then was born the idea of connecting the small system together in consolidations of companies, thus realizing obvious economies in investment and operation. As is usual, the opportunities for making a quick dollar attracted men of greater enterprise than integrity and the business suffered greatly from their operations. But power supply had a destiny to fulfill and the depredations of a few money-hungry men failed to stop the work of the many honest others who built soundly for the future. These were the early days, the 1880-1900 period.

Radius of Service Increased

In the later years of this period came the transformer and the induction motor, bringing alternating current strongly into the electric service picture. The radius of energy supply was greatly increased, was no longer limited by the low voltage of direct current service. Power companies extended their lines from the central districts of cities out into the residential areas and beyond to suburbs and adjacent rural communities. More and more companies were started until practically every sizable community could boast electric service. This period lasted until the time of the first World War when, in 1917, U. S. Census data show more power companies in operation than before or since. (See chart and table.)

During these years the techniques of electricity transmission developed greatly. Also there occured what,



PROGRESS in the art of electricity transmission was responsible for the decline in number of power companies that began in the early 'twenties. System integrations following passage of the Holding Company Act in 1935 reduced the number further

more than any other single thing, is the reason why this country soon took, and has since maintained, the lead over all other nations in electrification of industry, commerce and home. This was agreement on 60-cycle frequency. Following came standardization of lamp bases, receptacles, plugs and numerous other equipment and service elements which simplified the production and lowered the cost of electrical goods and made them usable anywhere in the country.

In contrast to this was the diversity of service conditions and consequent stunting of growth electrically in other countries. In ELECTRICAL WORLD, October 9, 1926, Viscount Rothermere, publisher of the London "Daily Mail" is quoted:

"So fast and far is the electrification of the United States extending that unless we (Great Britain) make an immediate effort to keep pace with her, we shall soon lag as far behind America industrially as the Balkan states are behind ourselves."

In the 40 years to 1920 the power companies had grown from nothing to a generating capacity of just over 12 million kw. In the next 10 years their capacity increased to more than 30 million kw. When Lord Rothermere looked at electrification in this country in 1926, the industry was growing 7 times as fast as it had been before 1920. What was happening was the same as had happened in miniature in the 20 years to 1900 when the small direct current systems of the larger cities were being hooked together and the potentialities of alternating current distribution and transmission began to unfold. But the stage was vastly enlarged over the earlier day. Instead of consolidations affecting only urban and closely adjacent areas, promoters—honest and otherwise—could encompass states and regions in their plans. Recognizing the "otherwise" kind, ELECTRICAL WORLD spoke strongly against them. In a timely editorial* is the remark, "The industry had just such individuals to contend with 30 years ago."

The accelerated expansion of the power companies after 1920 was not an isolated phenomenon. It was part of a national, a world-wide, period of business prosperity when, after the fearful times of war, enduring peace among the nations was thought to have come. Everyone dealt in futures, saw profits now and greater gains ahead. The stock market bid-and-asked prices were the daily concern of the barber, the professor, the street car motorman and the boy who mowed the lawn. In this picture the power companies were front and center. Companies were combined and stocks were issued; they changed ownership and stocks were issued; they built new plants and stocks were issued; they interconnected and stocks were issued; they were juggled about between holding companies and stocks were issued. And the public bought the stocks in eager, greedy, hope of doubled value overnight.

Disappointment, Deep and Bitter

Then came October, 1929. The power companies, riding highest on the wave, dove deepest in the following trough. Electric service empires crashed and great names that had spelled money to millions of people holding stocks for big profits were turned into bywords, bitter on the lips of those who saw their hopes of gain destroyed. Outstanding among these names is that of Samuel Insull who died, an exiled man, in a Paris subway station. To him most truly apply the words of Marc Antony over Caesar's body, "The evil that men do lives after them, the good is oft interred with their bones." Certainly Samuel Insull did great good by his pioneering in the development of transmission lines, of steam turbines, of system integration, of commercial operations, and of other aspects of electricity supply—great good, now buried in obloquy.

While the lust for easy money was bidding their stocks to heights that caused power company heads to state publicly that the securities simply were not worth the prices reached, as high as 40 times earnings, two other things were happening, one good, one bad—bad at least for the power companies.

The good thing was the accomplishment of a tremendous expansion in electric service and of the facilities to supply it. As stated earlier, generating capacity was increased at a rate 7 times as fast as in the previous 40 years. Transmission lines were built, tying small systems into big ones, thus allowing improvement of

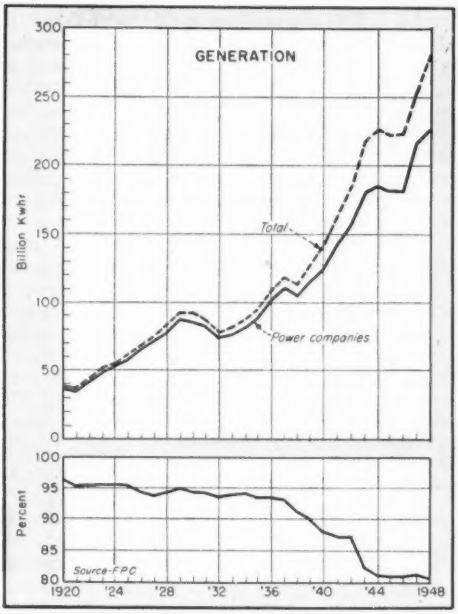
Number of Electric Supply Systems In the United States[1]

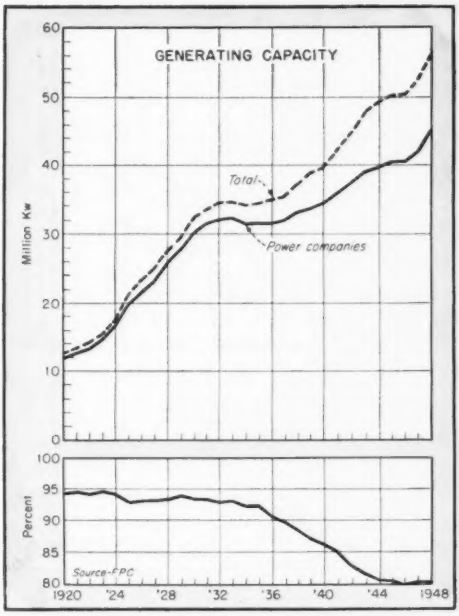
Year	Total	Private	Municipal	State and Federal	Cooperative[2]
1948	3950	776	2173	76	925
1947	3925	858	2107	73	887
1942	4046	1089	2074	65	818
1937	3501	1407	1888	25	181
1932	3429	1627	1802	....	....
1927	4335	2135	2198	....	....
1922	6355	3774	2581	....	....
1917	6542	4224	2318	....	....
1912	5221	3659	1562	....	....
1907	4714	3462	1252	....	....
1902	3620	2805	815	....	....

Source: Federal Power Commission. Data for 1937 and prior years U. S. Bureau of the Census, Census of Electrical Industries.

[1] Excludes generating plants owned and operated by commercial, industrial, and governmental establishments producing primarily for the use of such establishments. Total number of these plants with capacity of 100 kw and more in 1947 was approximately 4,500.
[2] Includes public power districts.

* Oct. 30, 1926





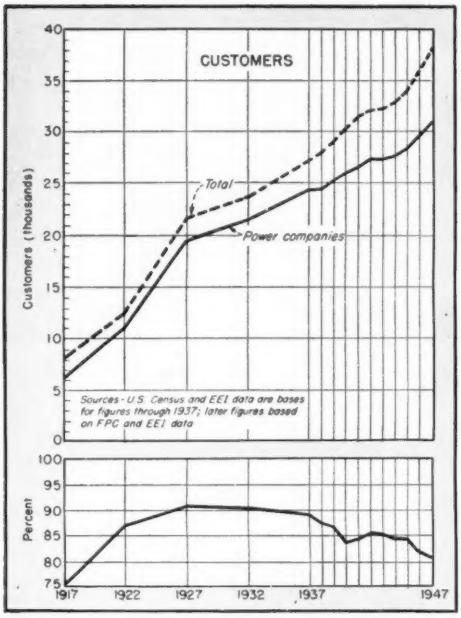
ENERGY OUTPUT of power companies in 1948 was 6 times what it was in 1920, while their capacity increased to less than 4 times. In the same period their shares in total power supply to the public decreased—in generation from 96.6 to 80.8% and in capacity from 94.4 to 80.2%. During the same period the number of companies decreased from approximately 3,800 to 776

economy in production and in all other phases of operation. Larger generating units and other betterments in power plant design and functioning practically doubled the efficiency of production, brought the average amount of coal per kwhr down from 3 lb in 1920 to 1.62 in 1930. Service was brought to many new millions of people; number of customers rose from around 11 million to well over 24 million in the decade. People living in electrically lighted dwellings increased in number from 37 million to over 83 million, the proportion of population served rising from 35 to 68%. In terms of solid achievement in electrification of the nation the 1920 decade was the greatest the power companies have known.

The bad thing for the power companies that occurred in the 20's was the conjuration of the "Power Trust" bogey. Minor magicians had been around since the beginning of the industry warning the people of the devils residing in business enterprise supply of electricity. But they could not make the people see the demons, not in any great number. It was not until the big league wizards began to shout their incantations that the malignant shape of the "Power Trust" took form in the eyes of the people. The first spell was recited in the 68th Congress in 1925, in a Senate resolution directing the Federal Trade Commission to investigate and report on allegations that the power companies were being controlled against the best interest of the nation. The FTC found no evidence of such control and so reported to the 69th Congress in 1927. (Senate Document No. 213) But the resolution and the investigation provided an appropriate stage setting in which to materialize the monster. Politicians of all stripes and calibers immediately set to work and so well did they fix the "Power Trust" in the minds of the people and so strongly was it cemented there by later political necromancy that common sense and cold fact have not yet been able to remove it.

In 1928 a senatorial investigation of the power industry was proposed. This eventuated in another FTC investigation which dragged out for years and resulted in dissolution of the National Electric Light Association and formation of the Edison Electric Institute as successor in 1933, and also in passage of the Federal Power Commission and Holding Company Acts in 1935.

The stock market break in 1929, which began the long depression of the '30's, greatly worsened the political situation of the power companies. It did not, however, hold them back from yeoman effort to stem the tide of depression at the behest of the President of the United States. He asked all industry, particularly the power industry, to go ahead with plans for expansion in order to provide employment and help to restore business confidence. The response of the power companies was to undertake for 1930 a construction program budgetted at over $913 million and on which $960 million was actually expended. This was the highest budget in the then history of the industry and stood as a record until 1947. For 1931 a construction expenditure of $894 was set, but this time business conditions had so deteriorated that the effort could not be maintained.



FEDERAL STIMULATION of municipal utilities in the 'thirties and growth of REA co-operatives caused decline in power company proportion of electric service customers

Compared with the '20's, the following years of the '30's might almost be termed a period of stagnation as respects the power companies. In 1932 the margin of reserve capacity for the whole industry (power companies and other suppliers) was 89% of the peak load. This is to say that for almost every kilowatt of capacity needed for work another kilowatt stood idle. It was not until this country entered the war that the margin of reserve was brought down to the 20% range, still higher than really necessary for safety of operation, but not entirely unreasonable. This condition of excess capacity was, of course, the direct result of the patriotically-inspired construction programs of 1930 and 1931.

Interest rates declined significantly in the depression years. The power companies took advantage of this reduced cost of money to refund outstanding bonds and other long-term debt. Refunding reached a peak of over $1¼ billion in 1936. These financial readjustments, plus rigorous economies in operation, enabled the power companies to maintain earnings at a satisfactory level that would otherwise have been impossible.

From the tough times of the '30's, the power companies came up to the war years lean and well-muscled. Their 36 million kw of generating capacity were in excellent shape. In the 7 years from 1934 they had installed 7.3 million kw but the increase in total of the period was only 4.5 million, 2.8 million kw having been used to replace obsolete and uneconomical machines. Corroboratory evidence of the improvement in power company plant comes from the fuel efficiency record, 1.47 lb of coal per kwhr in 1934 and 1.33 in 1941.

During the two years before this country entered the war, the power companies had been working mightily to build up generating capacity. In 1940 and 1941 they had installed 3.5 million kw, and they had large plans ahead. But these plans had to be cut back sharply in the war years because production of munitions and war material came first. About 1.7 million kw were installed in 1942, 1 million less than planned. Priorities and allocations kept capacity additions low 1933 through 1945 and labor troubles held them down in 1946 and 1947. Result was that the power companies were ill prepared for the great increase in demand for electricity that, contrary to expectations, came right after the war. Instead of leaving a large capacity margin, disposal of which would require extraordinary selling effort, the post-war load came close to requiring the entire available capacity. The reserve margin in 1947 and 1948 was around 5%, much too narrow for comfort.

Plans for Future Expansion

An immediate post-war projection* of capacity to be installed by the power companies covering 1946 and 1947, totaled 3.7 million kw. Actual new capacity in those years was only 1.9 million, because of continuing shortages of metals and of labor difficulties. Capacity additions in 1948 also fell short of plans, by about 0.5 million kw.

Thus it is that the power companies, because of conditions outside their control, have been unable for 8 years to expand as they should—and wanted to. Present plans* contemplate installation of over 17 million kw in the next 4 or 5 years, an increase over present size of about 40%, and requiring an outlay of up to $8 billion.

To maintain the 50-50 debt-equity ratio of capitalization that now exists and which continuing financial strength requires, the power companies will have to sell about $4 billion worth of common stock to investors in the next few years. In their two previous periods of great expansion the stocks of power companies were bought largely for capital gain. This incentive is lacking in present and future financing. Stocks will have to be sold for investment alone. It remains to be seen if this single inducement will be sufficient to attract the necessary money.

The financing problems of the power companies are not made any easier by the attitudes and intentions of men in high government places. Government competition in electricity supply has already made large inroads; some 20% of the business is now in government agencies. This proportion may increase.

Whatever their past, present and future difficulties, it cannot be denied that the power companies made this nation the leader of the world in electrification and are keeping it in the lead. And it must also be recognized that the potentialities of electrification are far from exhausted and that the incentives of business enterprise are needed for their full development.

* Electrical World, Jan. 19, 1946 and Jan. 29, 1949.

The Industrial Power System

Industrial plants consume more than half of today's electrical output Of the 7½ hp per worker more than nine-tenths is electric. Therefore, power supply and electrical distribution are engineered for reliability and economy

THE AVERAGE POWER that backs up each American factory worker has increased during the last half century from 2½ hp to about 7½ hp today.

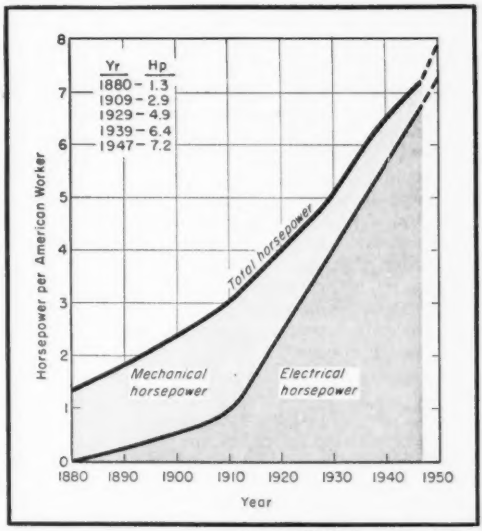
Forty years ago, less than 30% of the horsepower per worker was electric. Today about 93% is electric. And largely because of electrification, in 40 years the output per worker has tripled; and the value of the goods and services that he can purchase with one hour's work has more than doubled. Now, the biggest consumer of central station energy is the industrial plant. During the last 20 years the average rate dropped one-third while the average use increased six fold. Although today industrial plants comprise only about 0.5% of the total number of utility customers, they consume more than half the energy, and bring into the utility till about 30% of the total revenue.

Purchased Power

Most industrial customers buy their power because of the greater economy and reliability of large interconnected central station systems as compared to smaller isolated plants. Although both utilities and industrial plants are each generating more power, the increase for industrial plants is at a much lower rate. Industry is progressively generating a smaller part of its own power demand: It has dropped from about 40% in 1939 to about 33% in 1948 and will probably be only about 30% by 1955. The main economic justification for an industrial plant to generate its own power is the presence of byproduct heat, gas, or steam. Generally, any needed additional power can be purchased more cheaply than generated by burning prime fuel.

But sometimes industrial plants still find it pays to generate part or all of their own electric power. Depending upon conditions, plants may supply all their own power, supplement purchased power, or interchange power with utilities. Two of the most common industrial power-generation conditions are: (1) The use of low pressure steam for heating or processing and (2) availability of byproduct fuel or heat.

Even when "free fuel" is available economics often favor buying power. For example, operation of the new Big Inch and Little Inch gas line will depend entirely on purchased electrical energy. When completed, 1 billion kwhr annually will be used to transport the 500 million cu ft of natural gas per day by the line.

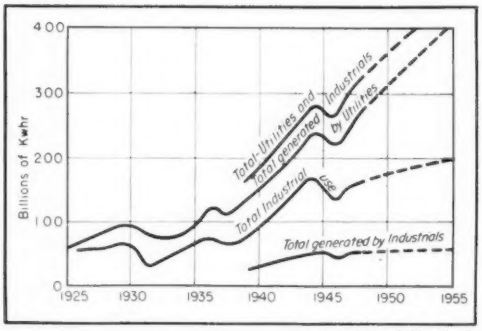


Courtesy Westinghouse Electric Corp

MORE ELECTRICAL HORSEPOWER is being used by American workers. About 93% of the industrial hp is electric

Gas Turbines

Gas turbines may give utilities a new flexible tool for supplying power to industrials. Gas turbine units can be moved from one location to another without much capital loss. They can be applied in an industrial plant in multiple, light weight units, which means flexibility. Industrial plants historically face the danger of quick obsolescence or a new process putting them out



Courtesy General Electric Co

MORE PURCHASED ENERGY is being used by industrial plants. Although both utilities and industrials are generating more and more energy, the industrial curve is rising much slower

of business. Because of this, they usually require about twice the rate of return a utility expects for the same risk. Therefore, utilities should be able to finance industrial power supply on a more economical basis.

Another promising possibility is for the utility to supply the industrial plant with both steam and electric power. One of today's noteworthy installations is Gulf States Utilities Co sales to the industrial area of Baton Rouge, La. During the last 18 years, the utility has supplied 155 billion lb of steam and 5¼ billion kwhr representing an income of $34 million.

Instead of supplying all the power, central stations may find it profitable to tie-in with a plant and exchange power. Last year, industry ordered for their own use boilers that potentially could produce about 1.5 million kw of byproduct generating capacity.

Although this potential will not be generated, a few process industries may produce more power than they use. For example, it has been estimated that a mill requiring 200,000 lb per hr process steam can generate: 0 kw at 150 psi; 4,600 kw at 450 psi; 9,600 at 1,000 psi, 23,000 kw with mercury turbines; and 66,000 kw with gas turbines. If the plant used a mercury installation, for example, they would have 18,000 kw excess to sell. For firm power, the plant would have to install a condenser and controls. On the basis of $150 per kw, this would be the equivalent of a $2.7 million utility plant.

Electrical Distribution

But whether an industrial plant buys power in large quantities or generates its own, the best means of distributing the power is an increasingly important problem with today's large plants. For example, the type of system, distribution voltages, short circuit protection, and interconnection of power and lighting circuits are typical questions that must be answered.

The vast wartime expansion woke up industry to the inadequacy of patchwork additions to industrial power systems. Today, most new industrial power systems are planned and engineered as carefully as if they were each a small utility.

In general, perhaps the correct selection of (1) voltage and (2) system arrangements do more to avoid power system bottlenecks, than any other two factors.

All in all, the industrial power system is more than keeping pace with plant needs. Reliability and efficiency of the power supply and distribution system is steadily improving. More flexibility, safety, and ease of maintenance is being designed into equipment. And the steady flow of new developments insure that industrial power systems will be even better tomorrow.

Motor Kwhr per Worker

Industry	Motor Kwhr	Industry	Motor Kwhr
Apparel	500	Miscellaneous	900
Chemical	1,600	Paper	26,500
Electric Machinery	1,400	Petroleum	28,800
Food	5,400	Printing	1,800
Furniture	3,100	Rubber	9,700
Leather	1,300	Stone	12,900
Lumber	3,100	Textile	5,500
Machinery	1,700	Tobacco	1,400
Metal	7,500	Transportation	3,000

Approximate Distribution of Electric Energy

Industry	Lighting	Motors	Electrolytic	Electric Furnace	Other
		(All figures are Percent)			
		MANUFACTURING			
Food	11	87	2	*	*
Tobacco	15	84	*	—	*
Textiles	10	89	*	*	*
Apparel	34	65	—	—	1
Lumber	12	85	*	—	2
Furniture	12	86	*	*	2
Paper	4	93	2	*	*
Printing and Publishing	20	75	*	2	2
Chemicals	4	45	22	28	1
Petroleum and Coal	6	94	*	*	*
Rubber	12	87	*	*	*
Leather	15	84	*	*	*
Stone, Clay and Glass	6	88	*	4	1
Iron and Steel	7	72	*	19	2
Nonferrous Metals	3	20	61	15	1
Electrical Machinery	19	43	2	30	6
Machinery	20	59	*	14	6
Automobiles	19	68	*	7	5
Transportation Equipment	27	47	*	9	17
Miscellaneous Products	18	73	*	5	3
All Manufacturing	8	62	14	14	2
		EXTRACTING			
Metal Mining	3	97	*	*	*
Coal Mining	4	92	*	*	3
Nonmetallic Mining	5	95	—	—	*
Petroleum and Natural Gas	8	90	*	—	2
All Extracting	4	94	*	*	2
		GOVERNMENT			
Shipbuilding	36	45	1	*	17
Arsenal and Ordnance	23	62	9	5	1
Miscellaneous Mfg	2	22	*	74	2
All Government	15	40	4	38	3
UNITED STATES	8	63	13	14	2

*Less than 1% Source: FPC, Industrial Electric Power 1939-1946

Municipal Electric Systems

Rapid increase in number up to middle of the '20's, then a decline which was reversed by the New Deal. Proportion in national total now about the same as 25 years ago

At the end of 1948 there were 2,173 municipal electricity supply systems in this country. With some outstanding exceptions, all of the systems are small compared with the average power company. The reason for this difference is that municipal systems in general are restricted in service operations quite closely to the corporate limits of their communities. The legal impediments that cause this restriction also prevent the utilities of different communities from joining together into large area systems as has been done by power companies.

(It should be stated, before going further, that the designation, "municipal electric utilities," as used here, does not include federal undertakings, power districts, state projects, or co-operatives.)

Total capacity of municipal systems and energy produced by them in 1948 were 4,078,350 kw and 13,119,000,000 kwhr respectively. In proportion to national totals, these figures place municipal utilities at 7.2% of capacity and 4.6% of generation.

In 1902, about half a century ago, there were 815 municipal systems. Their combined capacity was 113,000 kw and their generation 195,904,000 kwhr. Proportional to national totals, municipal systems represented 9.3% of capacity and 7.8% of generation.

Distribute Purchased Energy

It would seem, from comparison of these 1948 and 1902 proportions, that municipal utilities have declined considerably in the national picture, down from 9.3 to 7.2% in capacity and from 7.8 to 4.6% in generation. But this comparison is a misleading one. The reason for the declines in the ratios is the fact that as time went on municipal systems more and more confined their operations to distribution alone, purchasing energy at wholesale from power companies and also in later years from federal and state undertakings.

"Then and now" comparison of municipal utilities in respect to number of customers cannot be carried as far back. The earliest available record of customers is 977,000 on 1917. At the end of 1947 these utilities are estimated to have had 5,143,000 customers. These figures are 12 and 13.4% respectively of national totals. Thus in 30 years people served by municipal systems increased slightly in proportion in the national picture.

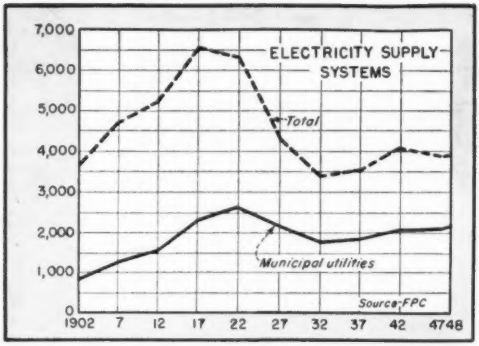
An accompanying curve shows changes in number of municipal systems from 1902 to 1948. It is to be noted that the number increased quite rapidly to 1922. The increase resulted partly from activities of municipal ownership zealots, partly from lack of local enterprise to undertake a service the people wanted, and partly from financial difficulties encountered by power companies already in operation. Then occurred a decline continuing to 1932. The reason for this decline is directly associated with the great power company expansion of the '20's. As the transmission lines of the companies were extended, linking them into larger operating units, municipal utilities were bought out and incorporated in the newly integrated systems.

Federal Grants Offered

An upward trend of the curve began with the change in national administration in 1933. In attempt to better conditions of the then depression times, the federal government undertook a large program of public works and offered inducements to local governments to do the same. A form of this effort was the Public Works Administration which made grants of federal money to the local governments in order to help them build. Particular attention was directed to the encouragement of municipal electric utilities, grants of up to 45% of cost being offered.

Another factor favoring increase in municipal systems was invention of the "revenue" bond and its acceptance by investors. Previously these systems had been financed on the general credit of the municipalities; bonds secured by the tax rolls were sold to pay for power plants and system facilities. But during the depression years the general credit level of municipalities was low and in many instances cities were unable to sell new bonds because their debt limits set by state laws had been reached. The way out of the impasse was found in the revenue bond. Instead of being an obligation secured by general taxes, it was a lien on the revenue of the utility built with the proceeds of its sales. This financing device, plus federal money to pay a large part of the cost, made municipal electric service look very attractive.

In view of these encouragements of municipal ownership the remarkable thing is not that the curve moves



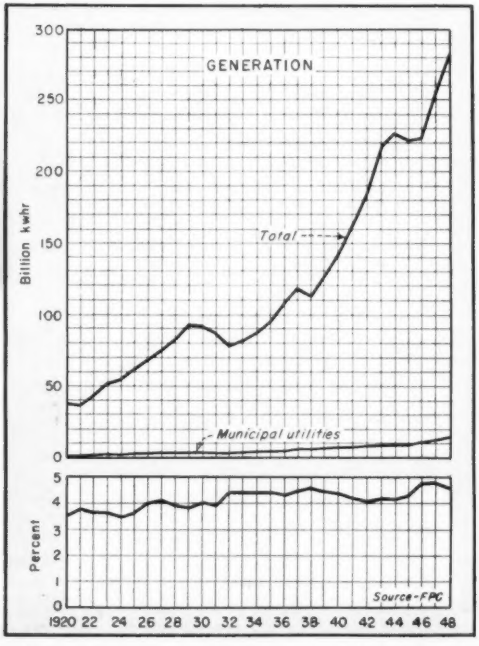
PEAK in number of municipal electric utilities was reached in early 'twenties. Ensuing decline was caused by power company take-over as transmission lines were extended

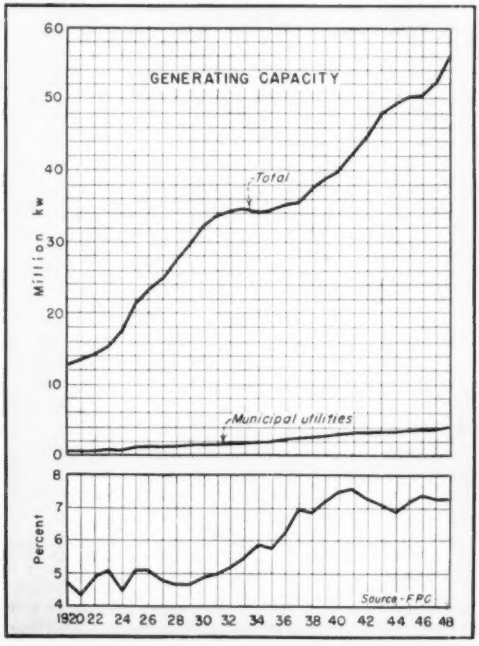
upward from 1932 but that its ascent is not much steeper. A discussion of "Municipal Ownership Trend" in ELECTRICAL WORLD,* covering 1,052 municipal plant and franchise elections, 1933-1943, says:

"In the 11-year period 503 elections went in favor of government ownership and 549 against. More than half of the elections, 549 of them, occurred in the first 5 years of the New Deal, and only 292 of these, or a little more than half, went for municipal ownership or rejected franchises to power companies. And these were the lush years of the 45% PWA handouts. The 6th was the last year of PWA largesse and strenuous efforts were made to coax passengers aboard the gravy train. The result appears in the 218 elections held that year, and of these, municipal ownership did not win as many (110 vs 108) as, considering the circumstances, might have been expected. In the 5 remaining years of the period, 285 elections were held and 184 of them, about 64%, favored the power companies."

Exceptions from the average small size of municipal systems were noted at the beginning of this article. Among these are Los Angeles, Seattle, and Tacoma on the Pacific Coast; Chattanooga, Knoxville, Memphis and Nashville in the TVA area; and Omaha, Nebraska. In the three first-named cities, municipal electric service has been established for many years. In the others the utilities were taken over from power companies in the drive for government ownership of the 30's. By their size these utilities are able to realize many of the economies of operation and management that caused the power companies to coalesce into large units. But these and other exceptions are few; the greater number of municipal electric utilities labor under the disabilities that inhere in small, isolated operations in a field whose principal features of economy are large scale production and integrated operation. Politics also may be a factor in some cases.

* January 22, 1944.





PROPORTIONATE to total generation, municipal utility output increased only 1% in 29 years while its capacity proportion increased 2.6%, although number of consumers served by municipal systems multiplied about 5 times in the period. Reason is purchase of energy from federal plants and power companies for local distribution by municipalities

Federal Power Systems

Federal power's history, now 60 years old, spans two eras, one of which was confined largely to policy-making, the other to policy and construction. Now, with the authority to build steam plants, a third era seems to have dawned

FOR ALMOST exactly 60 years, the United States' participation in public electricity supply rested upon the twin Constitutional provisions for federal jurisdiction over navigable waters and the public domain. Federal power's growth, both in policy and operations, from its inception in the Act of Sept 19, 1890, has rested on these twin powers.

Obviously, the injection of an entirely new legal concept as to the federal government's sphere in electricity supply came with the First Deficiency Appropriations Act of April, 1949. This gave specific legal sanction—through money—to the first non-emergency construction by the United States of thermal-electric properties whose output is to be devoted to a general commercial power business. Thus federal government now has a third base upon which to build its power operations. As a result, federal power undoubtedly began its third era with this legislation.

The two preceding eras are roughly equal. The first began with the Rivers and Harbors Act of 1890. In large part, it was confined to the development of basic policy. There was some federal construction and operation by the Reclamation Bureau. But it totalled only 34,900 kw by mid-1920, at this era's close. Legislative capstone of this era was the Federal Water Power Act of 1920. This saw the consolidation in one act of the significant policies of the previous 30 years and many more proposed often without general acceptance.

Principles Established

During this era, there were laid down the principles that any obstruction of a navigable stream must be approved specifically by Congress, with plans cleared by the War Department; that rights of way might be granted across public domain; that licensees might be required to build or contribute to navigation works; that preference in the sale of federal energy be accorded public bodies; that "built-in" power features be provided at federal navigation dams even without immediate power development; that net investment be the valuation standard; that grants might be repossessed after 50 years; that fees might be charged; that federal control might govern licensed project rates, securities and accounting; that licenses might be "conditioned;" that developments be comprehensive and many more.

Federal power's second era—mid-1920 through early 1949—started slowly. Major achievement of its first half was the Boulder Canyon Project and its Hoover Dam. Not only did this project's dimensions make it far and away the greatest of any such federal project up to that time; but also the legislation governing power development and disposal there set a wholly new standard in federal power, one which has been uncopied since. It was the first of the mammoth water development works which have become so popular with government power planners. It provided for non-federal power systems, public and private alike, to make the actual power development investment and do the marketing job, using the federal investment in the dam itself and paying for the privilege.

Federal Power Expands

In any realistic sense, the construction and operation of federal power systems began early in 1933. This year opened the last half of the second federal power era. The stage was set then for large scale development of federal power. It was an era when work relief constituted one of the largest items in the federal budget. It was an era of reform which rapidly became one of business crackdown. The times were conditioned by the Federal Trade Commission investigation of electric utilities, which began in 1928. It was an era of broad expansion of government functions. Each of these helped broaden federal power expansion.

This half of the second era kicked off with one of the most significant pieces of federal power legislation of all time—the Tennessee Valley Authority Act. The act, its amendments and its successfully-asserted interpretations established the concept that the United States might assume partial or complete responsibility for area power supply. It implemented the concept of using power, widely distributed at minimum rates, as a tool for regional economic and cultural development.

In 1936, the federal government assumed responsibility for flood protection and prevention. This move vastly augumented federal power by giving the Army many more dams to build, many more of which were located much more advantageously for the generation of power, than the Army dams envisioned earlier under Rivers and Harbors jurisdiction.

Marketing Jurisdiction, Mw

	Bonneville Power Administration[1]	Southwestern Power Administration[2]
Now Marketed		70
Army	518	
Reclamation	992	
Being Added in Existing Plants		70
Army	0	
Reclamation	992	
Being Built in New Plants		361
Army	1,096	
Reclamation	286	
Authorized for Construction		221[3]
Army	2,260	
Reclamation	22	

[1]On June 30, 1948, Bonneville owned and operated 3,293 miles of transmission and 36 substations with 2,765,333 kva of capacity.
[2]On June 30, 1948, SPA had 530 miles of transmission and one substation under construction.
[3]Two of these projects, totalling 39,000 kw, are authorized "but probably never will be built."

The Bonneville Project Act, a year later, developed the independent power marketer concept and provided a tool for regional development of a federal power system which was not organized as a valley authority.

The Reclamation Project Act in 1939 made it easier for Reclamation to develop more and bigger power projects.

And all this time, much new construction was going on—the big new plants at Bonneville and Grand Coulee, Shasta, Parker, Davis, Denison and Norfork were being built and designed. Truly, from 1933 to the war, federal power developed much policy and plant.

Federal power didn't by any means stand still during the war. TVA added a steam plant, at least three major new dams and numerous additional units. Bonneville filled its powerhouse and Grand Coulee filled one of two. Policywise, there wasn't much change until the Flood Control Act of 1944 turned over to the Interior Department the marketing of Army-developed energy.

Early in the postwar era, federal power construction was hampered by cost, economic and political difficulties. All have been thrown to the winds by now, and the actual construction program underway or being advanced to the appropriation stage dwarfs the best that federal power was able to do during its vast ascendancy of the last 16 years.

When the possibilities of federal steam back-up for isolated power plants at flood control, reclamation or navigation dams are contemplated along with the wide demand for federal spending and the ramified development of federal power policy, the prospect is inescapable that federal power's third era will see new extensions of federal regional power supply responsibility.

Even without counting any steam capacity the federal government may erect under its new authority, it has a broad program laid out for power expansion. More than 1,750,000 kw are being added in existing federal hydro plants now. Under construction in new federal plants are 4,269,500 kw of new capacity, including TVA's New Johnsonville steam plant. And authorized for construction are another 4,197,000 kw. Plants proposed for construction go well beyond these totals. Reclamation alone proposes 4,275,000 kw. Total cost of all federal water projects, including those with hydro-electric power which are underway, proposed or authorized, is about $40,000,000,000.

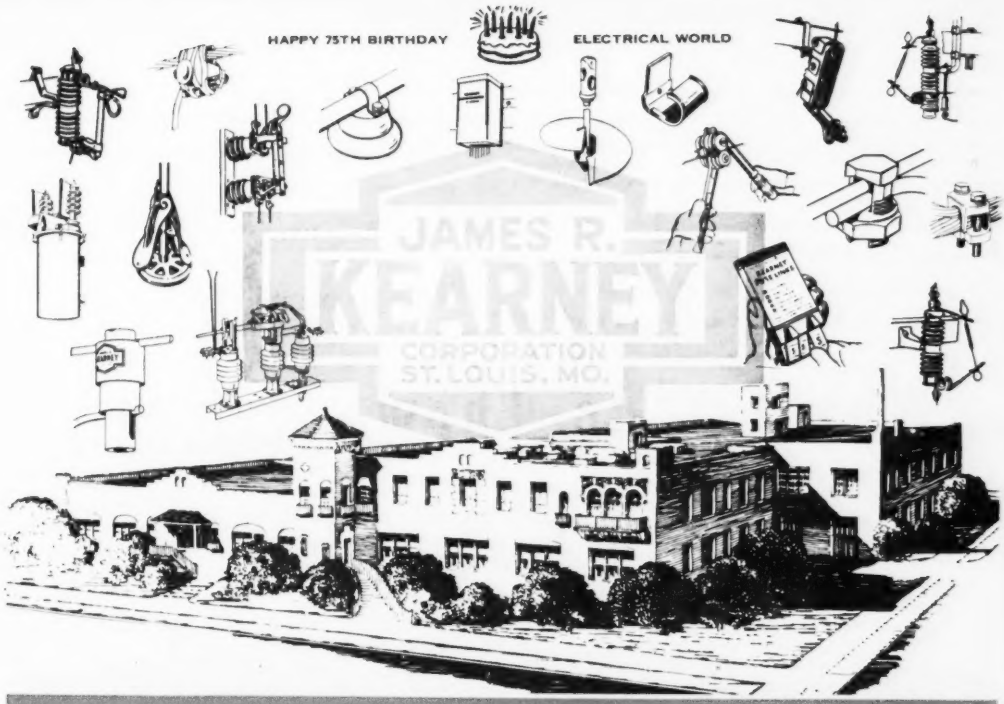
Today, of course, federal power holds area supply responsibility in the Tennessee Valley. Essentially, although far from completely, it holds area supply responsibility in the Pacific Northwest. It is heading toward comparable responsibilities in the Missouri valley, and has possibilities in the southeast, the near southwest and the far southwest.

Organizationally, federal power's pattern is divided between the construction-operation and the marketing functions. TVA, of course, does both. So does the Reclamation Bureau. The Army Engineers only build power plants, and the Bonneville and Southwestern Power Administrations only market power over lines they construct.

Megawatts of Generating Capacity and Marketing Jurisdiction of Three Government Agencies

	United States Bureau of Reclamation[1]		Corps of Engineers, United States Army		Tennessee Valley Authority[3]	
	Generating Capacity (Mw)	Marketing Jurisdiction (Mw)	Generating Capacity (Mw)	Marketing Jurisdiction (Mw)	Generating Capacity (Mw)	Marketing Jurisdiction (Mw)
Operating	1,459.6	467.6	674.4	0	2,567.4	2,603.4[5]
Owned	1,482.7	467.6	674.4	0	2,256.3	2,256.3
Being added in existing plants	1,297.0	150.0	122.0	0	357.0[6]	357.0
Being built in new plants	838.6	1,478.6[2]	2,970.9	16.4	460.0	865.0[6]
Authorized for construction	619.0	1,275.0[2]	3,562.0	0	.....	.....

[1]USBR owns and operates 2,800 miles of transmission line.
[2]Includes Army-built capacity to be marketed by USBR.
[3]TVA had 6,676 miles of transmission line on June 30, 1948.
[4]30,000 kw going in Alcoa's Cheoah Dam plant.
[5]36,000 kw of Army capacity at Dale Hollow being marketed by TVA.
[6]Includes 405,000 kw of Army capacity at Center Hill & Wolfercek for marketing by TVA.



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Better Construction – *SAFER* Maintenance

"Committee:
A body of persons appointed or selected to consider, investigate, or take action upon, and usually to report concerning, some matter or business, as by a court, legislative body, or a number of persons."
Webster's New International Dictionary, Second Edition.

Why Not Do Them Justice, MR. WEBSTER?

THE 950 members of Edison Electric Institute committees would question your definition, Mr. Webster.

To them, "committee" means hard work — honest sweat — frequent meetings — trips away from home — after-hours study — time borrowed from their regular jobs. It means long hours spent on projects which may not be completed for years. It means the expenditure of much time and effort for which, at first glance, they are not repaid.

Yet, fortunately for the electric industry and for the American public, there have always been men and women willing to shoulder this extra burden . . . willing to work for companies whose payrolls will never list their names, for customers thousands of miles away from their own company service areas.

EEI and its predecessor have been built around such groups almost as long as there has been an "Electrical World." And many of them have played an important part in making today's world so largely electrical.

Since 1885, these industry committees have been engaged in an unremitting struggle to improve every operation involved in producing and distributing electric energy, to make America's electric service ever more adequate, dependable and efficient.

Engineering committees, whose field includes everything from boilers to outlets, can point to scores of their ideas now at work in the generating, transmission and distribution facilities of hundreds of companies.

Commercial committees have developed promotional programs that have helped to transform brand-new appliances into necessities in millions of American homes, and have assisted the industry's sales forces in every phase of their work.

Accounting committees have standardized principles and simplified techniques that record the history of utility equipment from the original financing of its purchase to final disposition as scrap.

Other committees have made major contributions to the industry's statistics, transportation, industrial relations, rate research and similar important fields.

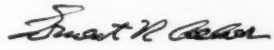
Out of EEI committee meetings have come, for example, reduced insurance rates that save the industry millions of dollars annually. (The EEI Insurance Committee has saved the industry a sum greater than the total amount of dues received by the association during its history!)

All of these activities are assumed voluntarily by committee members—all, seemingly, are unrewarded. Yet there is never a lack of candidates for committee posts, eager for the invisible rewards which await them. It would be difficult, in fact, to name any outstanding industry executives who have not at one or more times in their careers served on an association committee.

Committee members have the opportunity to serve an entire industry rather than one company only — to widen their knowledge, form helpful friendships and absorb new ideas. Their companies know that committee membership improves a man's working efficiency . . . that the give-and-take of committee meetings, the varied experience thus offered, are fine training for more responsible positions.

Thus, committees directly benefit the industry as a whole, the members and their companies. But the ultimate and real beneficiaries of all committee activity are, of course, the industry's customers.

The housewife enjoying effortless electric water heating, the factory manager solving a production problem with infra-red, the farmer harvesting new fields because electric equipment now saves time once needed for chores — these are the people who really benefit from committee work . . . for their electric service needs receive the attention of the best-qualified minds not only of one company, but of an entire industry, through the medium of its trade association.



ERNEST R. ACKER

President

Edison Electric Institute

DAY & ZIMMERMANN, INC.

ENGINEERS

FIFTY YEARS
OF INTERNATIONAL SERVICE
IN
BUSINESS REPORTS,
INDUSTRIAL ENGINEERING
AND
ENGINEERING DESIGN
AND CONSTRUCTION
IN WHICH WE HAVE SERVED
MORE THAN 4,000 CLIENTS

REPORTS
Business Reports
Service to Utilities
Rate Cases
Evaluations, Appraisals

INDUSTRIAL ENGINEERING
Organization, Plant Layout
Cost, Production
Wage Rates,
Wage Incentives
Labor
Material Handling
Machinery, Equipment
Methods, Products, Markets

DESIGN AND CONSTRUCTION
Boiler and Power Plants
Transmission Lines
Substations and Distribution Lines
Chemical and Process Plants
Industrial Plants
Manufacturing Plants

DAY & ZIMMERMANN, INC.

ENGINEERS

PHILADELPHIA

NEW YORK CHICAGO

Greater Selectivity

means less interference . . .

AT HEADQUARTERS

THE NEW RCA STATION RECEIVER
Type CR-9A (152-174 Mc)

ON THE ROAD

THE NEW RCA CARFONE
Mobile 2-way FM radio, 152-174 Mc

. . . you get the greatest selectivity with RCA's All-New Communication Equipment

● You're going to hear a lot about selectivity from now on. In communication systems, receiver selectivity, more than any other single factor, determines the degree of freedom from interference. This is important both for today and for the future.

Recognizing this fact, RCA has taken the necessary steps to make its all-new communication equipment the most selective of any on the market today. To the user, this means reliable operation substantially free from interference. In addition, this greater selectivity now makes adjacent-channel operation a practical possibility—thereby greatly increasing the number of potentially useful channels for mobile radio communication systems.

For complete details on the new RCA Station Receiver type CR-9A, and the new RCA CARFONE for mobile use, write today. RCA engineers are at your service for consultation on problems of coverage, usage, or complex systems installations. Write Dept. 31-E.

Free literature on RCA's All-New Communication Equipment—yours for the asking.

COMMUNICATION SECTION

RADIO CORPORATION of AMERICA

ENGINEERING PRODUCTS DEPARTMENT, CAMDEN, N.J.

In Canada: RCA VICTOR Company Limited, Montreal

the Kite - the Key - and ELECTRICITY

A new industry was born.

Then American enterprise, knowing that water always seeking the lowest level creates a continuous source of energy, adapted the hydraulic turbine to the development of electricity.

For nearly 75 years, we have been builders of hydraulic equipment-with installed turbine capacity of almost 12 million horsepower!

Our knowledge and experience thus gained are at your disposal when you place your problems in our hands. Why not write — today?

S. MORGAN SMITH COMPANY

YORK • PENNSYLVANIA, U. S. A.

POWER by SMITH

THE

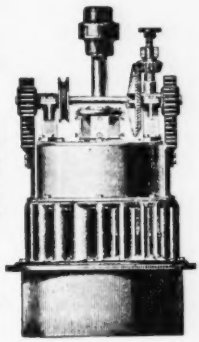
McCormick Turbine,

On Vertical or Horizontal Shaft.
Especially Adapted for Electric Work.

Gives more power per diameter with a higher percentage of useful effect than any Water Wheel heretofore made. All sizes of these wheels, right and left hand, are built from patterns perfected under systematic tests in the Holyoke Testing Flume at an expenditure of many thousands of dollars and years of time.

Parties having power plants which are unsatisfactory, and those contemplating the improvement of powers, will find it to their interest to confer with me, as I am willing to guarantee results where others have failed no matter what make of turbine has been in use.

State your requirements and send for catalogue.



S. MORGAN SMITH CO.,
YORK, PA., U. S. A.

Estimates furnished for Complete Power Plants and Results Guaranteed.

Yesterday

An early turbine following our original "Success" unit of 75 years ago

and Today

75 Years of Continuous Progress

which this installation of 10 Smith-Kaplan turbines at Bonneville well illustrates. Put your Hydraulic Problems up to us. Write for data.

S. MORGAN SMITH Co.
YORK, PENNA. U.S.A.

"... fundamentally, the business of the electrical industry

1923

An early General Electric advertisement states the goal of electrical service to all mankind.

The initials of a friend

You will find these letters on many tools by which electricity works. They are on great generators used by electric light and power companies; and on lamps that light millions of homes.

They are on big motors that pull railway trains; and on tiny motors that make hard housework easy.

By such tools electricity dispels the dark and lifts heavy burdens from human shoulders. Hence the letters G-E are more than a trademark. They are an emblem of service—the initials of a friend.

GENERAL ELECTRIC

has been the steadily increasing enrichment of human life"

1949

In current advertising, General Electric reaffirms this ideal . . . cites G-E achievements.

Our aim is to give you more than you expect

Take General Electric refrigerators, for example. A new and more efficient mechanism gives ⅓ more food storage with no more floor space needed . . . A new television tube gives brighter pictures you can see without sitting in the dark . . . The new G-E Sealed Beam headlamp gives you 12% more light on the road. Constant improvements through research and engineering make General Electric products serve you faithfully, deliver more than you expect.

You can put your confidence in—

GENERAL ELECTRIC

A. H. NICOLL
President
Started 1911, as a Sales Record Clerk

G. F. HESSLER
Vice President
Started 1906, as a Clerk

C. S. POWELL
Vice President
Started 1914, in the Student Course

E. W. CASHMAN
Vice President
Started 1913, as a Clerk

E. R. YONKERS
Detroit District Manager
Started 1933, as a Salesman

L. B. WESTFALL
Cincinnati District Manager
Started 1916, as a Service Clerk

D. WALLACE
Pittsburgh District Manager
Started 1922, as an Assistant Accountant

R. B. SAYRE
Jacksonville District Manager
Started 1921, as a Warehouseman

*824 years of electrical experience

**average service 34 years*

HERBERT METZ
New York District Manager
Started 1914, in the Student Course

C. H. McCLEAN
Minneapolis District Manager
Started 1913, as a Warehouseman

J. A. MAYER
Philadelphia District Manager
Started 1913, as an Equipment Installer

E. E. MARTIN
Boston District Manager
Started 1920, as a Service Clerk

A. C. LAMPERTI
Secretary
Started 1920, as a Bookkeeper

R. B. WILKINSON
Treasurer
Started 1915, as Errand Boy

J. P. CARSON
San Francisco District Manager
Started 1910, as a Salesman

G. J. COSSMANN
Chicago District Manager
Started 1900, as a Voucher Clerk

Graybar Officers and District Managers

ALL BEGAN IN THE RANKS

Ever since the first power lines were put up, Graybar has been providing first-quality electrical items to power and light companies, manufacturers, electrical contractors, retailers, and other commercial users.

Experienced men make an experienced organization — one that can serve you well.

Graybar, oldest and largest wholesaler of "everything electrical," has built its business upon two basic policies:

(1) serving customers well;
(2) filling key jobs from within.

Over the years, this second policy has developed office boys and clerks into department heads, district managers, and corporate officers.

With such opportunity for advancement, every Graybar employee has a powerful incentive to do his job well. Result: continual improvement in our service to a continually growing list of customers.

Graybar is *totally owned* by its operating and retired personnel. That's another reason why every Graybar employee is personally interested in meeting your electrical needs accurately, helpfully, on time. *Graybar Electric Company, Inc. Executive Offices: Graybar Building, New York 17, N. Y.* 4953

OFFICES AND WAREHOUSES IN OVER 100 PRINCIPAL CITIES

100,000 First-quality Electrical Items Are Distributed Throughout the Nation . . .

L. G. FIELDS
Jacksonville District Manager
Started 1924, as a Warehouseman

W. FRAZIER
Kansas City District Manager
Started 1911, as an Office Boy

A. D. HAMMOND
Atlanta District Manager
Started 1906, as a Clerk

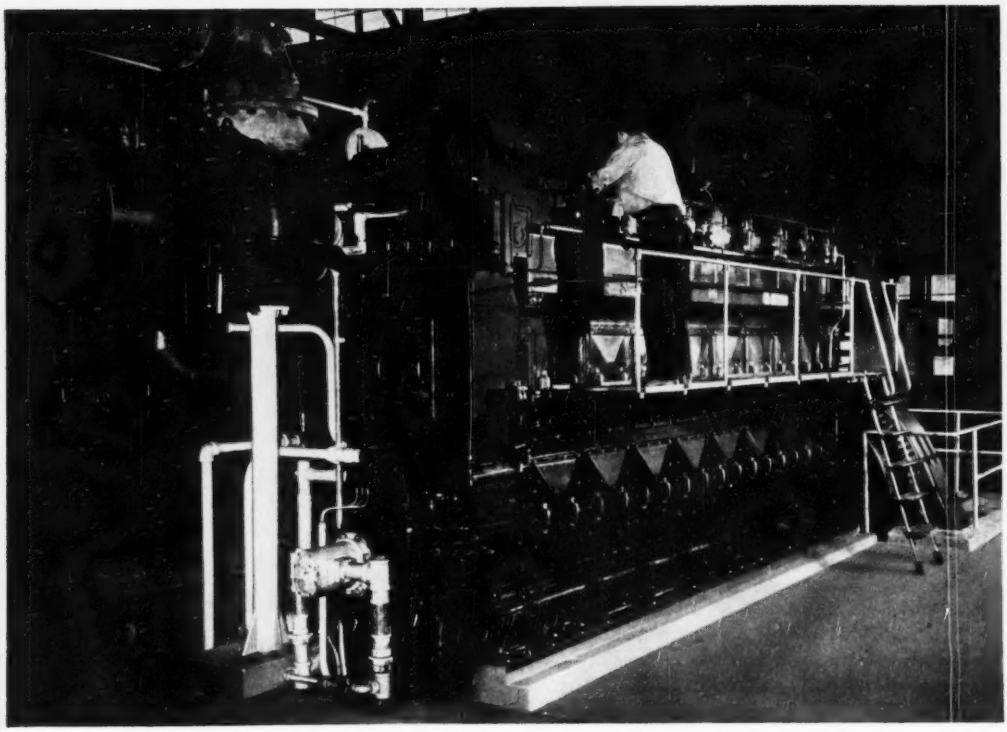
H. L. HARPER
Los Angeles District Manager
Started 1904, as a Stock Clerk

G. T. MARCHMONT
Dallas District Manager
Started 1908, as a Service Clerk

J. P. LAWTON
Seattle District Manager
Started 1923, as a Warehouseman

R. W. KIMBERLIN
St. Louis District Manager
Started 1922, as a Sales Record Clerk

W. E. HENGES
Cleveland District Manager
Started 1913, as a Receiving Clerk



THERE WAS WATER FOR EVERYTHING

... but only a trickle for power

In 1948 one of the largest power plants in the East was faced with a serious lack of water for hydro-electric power purposes.

They knew they had to prevent a power shortage ... so they decided to install a Diesel generating unit just as quickly as possible. Officials of this utility company contacted our Superior Engine Division and told them about their problem.

In just 72 days from the time the order was placed, Superior had delivered and helped complete the installation of a 1000 KW generator unit, powered by an 8 cylinder, 1440 hp. turbo-charged Superior Diesel. This installation proved so successful that recently they ordered another Superior.

Yes, you can depend on our Superior Engine Division for outstanding service whenever it is needed. And you can be sure that Superior Diesels will provide an equally dependable source of power. We would appreciate an opportunity of showing you the advantages they offer.

THE NATIONAL SUPPLY COMPANY
SUPERIOR ENGINE DIVISION
Plant and General Sales Office: Springfield, Ohio

THE NATIONAL SUPPLY COMPANY NSCO

Superior DIESEL

GILBERT ASSOCIATES, INC.

INTEGRATED *Service*
CO-ORDINATED *Knowledge*
CENTRALIZED *Responsibility*

The reason many progressive utilities use G A I year after year and that other wide-awake managements are continually joining its clientele is because they receive, under one contract, the broad experience of a well-integrated staff that has worked together over the years as consulting engineers and management advisors.

SERVICES OFFERED INCLUDE:

Engineering economics; Special engineering studies and reports; Engineering design and construction supervision; Chemical laboratory services; Management consultation; Public utility research and rate studies; Industrial research; Industrial relation service; Centralized purchasing; Safety service; Cost and tax accounting.

GILBERT ASSOCIATES, INC.

READING, PA.

Engineers and Consultants

NEW YORK • PHILADELPHIA • WASHINGTON • HOUSTON

GAI

Founded 1906

43 YEARS OF *Experience!*

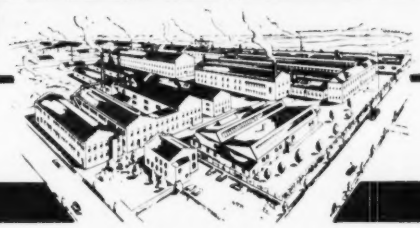
1906-1949

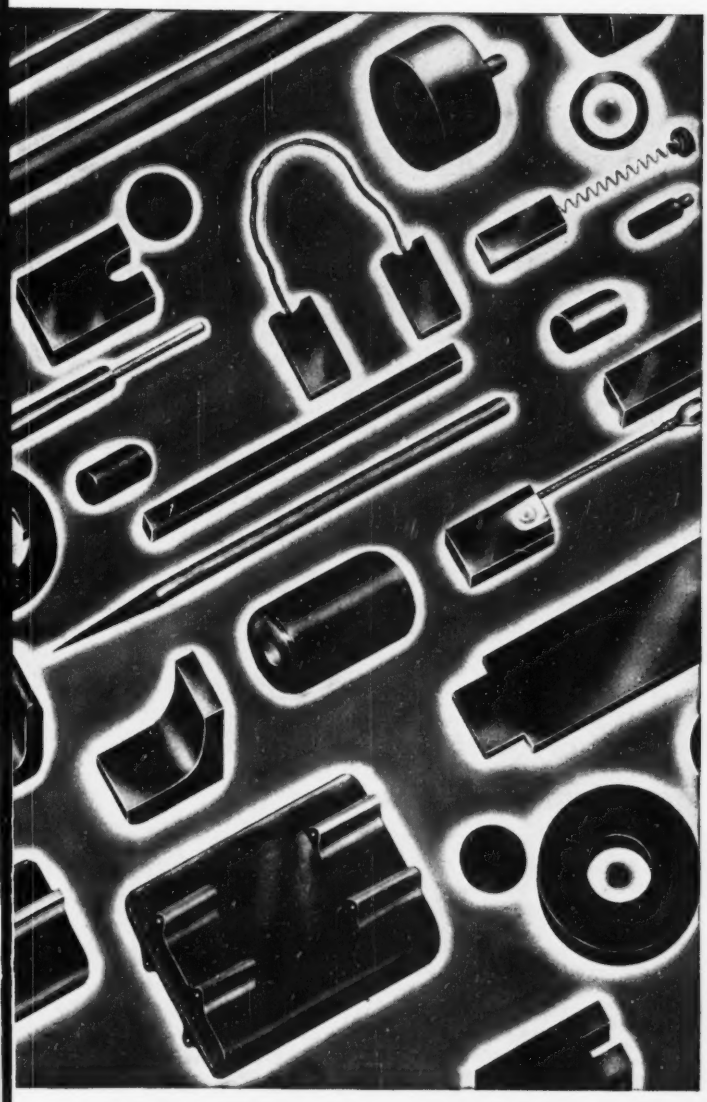
BRUSH HEADQUARTERS

As one of the world's oldest and largest brush manufacturers, Stackpole offers a complete line for all rotating equipment. Included are such specialties as high-altitude aviation brushes, high-altitude types for earth surface equipment, silver-graphite brushes, exceptionally durable universal and fractional h.p. motor brushes and many others. Sold only to makers of original equipment. Write for helpful brush data booklet 20 on your company letterhead.

CARBON, GRAPHITE and RARE METAL CONTACTS

By virtue of long experience plus the policy of engineering contact materials for each specific job, Stackpole has been signally successful in improving contact performance for leading manufacturers of original equipment. The big Stackpole Contact Booklet 12 contains a wealth of helpful data for dealing with contact problems.





CARBON and GRAPHITE SPECIALTIES

BATTERY CARBONS
BEARING MATERIALS
BRAZING FURNACE BOATS
CARBON PILES (voltage regulators)
CHEMICAL CARBONS
CLUTCH RINGS
CONTINUOUS CASTING DIES
DASH POT PLUNGERS
ELECTROLYTIC ANODES
ELECTRIC FURNACE HEATING ELEMENTS
FRICTION SEGMENTS
GLASS MOLDS
MERCURY ARC RECTIFIER ANODES
METAL GRAPHITE CONTACTS
POWER TUBE ANODES
RAIL BONDING MOLDS
RESISTANCE WELDING AND BRAZING TIPS
SEAL RINGS (for gas or liquid)
SINTERED ALNICO 2
SPECIAL MOLDS AND DIES
TROLLEY AND PANTOGRAPH SHOES
WATER HEATER ELECTRODES
WELDING CARBONS OF ALL TYPES

. . . and many others to solve problems of friction, temperature, corrosion, shaft sealing and arcing in a wide variety of applications. Write for details on any type.

ELECTRONIC SPECIALTIES

IRON CORES

. . . including standard frequency, high-frequency, cup, sleeve, screw, choke coil, permeability tuning, television horizontal deflection and fly back transformer cores and other types.

FIXED AND VARIABLE RESISTORS

INEXPENSIVE SNAP, LINE AND SLIDE SWITCHES (up to 3 amperes capacity)

Write for electronic components catalog RC-7

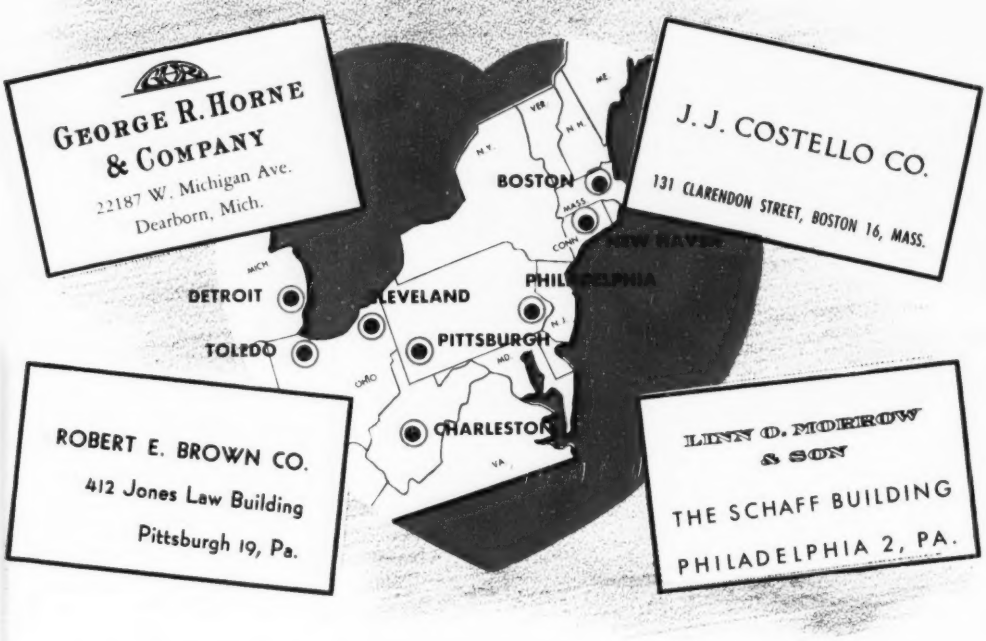
STACKPOLE CARBON COMPANY
ST. MARYS, PENNA.

STACKPOLE

"EVERYTHING IN CARBON BUT DIAMONDS"

SALES "KNOW-HOW"

Today's most important ingredient . . .



Representing 120 years of combined experience selling electrical equipment

J. J. COSTELLO CO.
Thirty years of service to the electrical industry in New England representing outstanding manufacturers of electrical products. Sales offices in Boston, Mass., and New Haven, Conn., and adequate warehouse facilities in Boston, Mass. Employ seven salesmen including three graduate Electrical Engineers, calling on Utilities, Consulting Engineers, Contractors, Industrial Organizations, Wholesalers, and Government Agencies. Efficient office personnel and corrected mailing list for general or specific mailings.

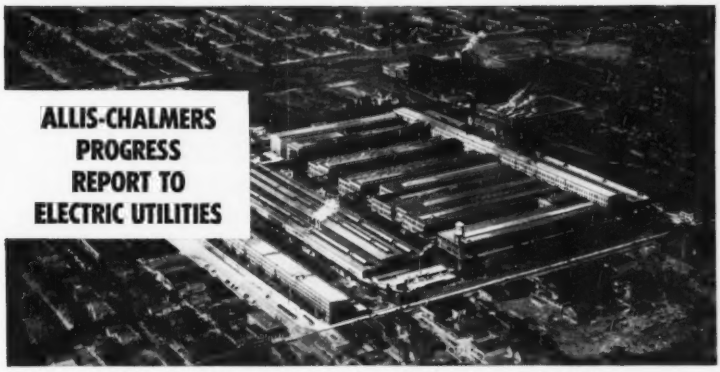
LINN O. MORROW & SON
Operating as a Manufacturer's Agent in the Philadelphia Territory since 1919, covering the eastern part of Pennsylvania, southern part of New Jersey, Delaware, Maryland, Virginia and the District of Columbia. Now Handling Graphic Recording Instruments, Testing Instruments, Lifting and Separation Magnets, Explosion and Weatherproof Equipment. Prepared to sell electrical apparatus noncompetitive with the present accounts.

GEORGE R. HORNE & CO.
. . . . . represents top flight manufacturers of electrical devices and apparatus. Salesmen cover all central and lower Michigan — representative in Toledo, Ohio, covers area including Toledo and Fort Wayne, Indiana. 30 years sales engineering experience selling consulting engineers, utilities, and industrial accounts. Complete mailing lists and facilities for direct mail advertising available.

ROBERT E. BROWN CO.
In business 22 years in the Tri-State District. Main office in Pittsburgh; Branch Offices in Cleveland, Ohio and Charleston, West Virginia. Contacts continually being made with industrial plants, electric utilities, consulting engineers, electrical wholesalers and contractors. Mailing lists constantly revised and corrected, and arranged for general or specific mailings.

● *Covering the Heart of Electrical Industrial America*

WE SOLICIT YOUR INTEREST IN OUR ABILITY TO DO A SALES JOB FOR YOU



WEST ALLIS WORKS—one of 9 plants, 65 sales offices, 33,000 employes serving U.S.!

WALTER GEIST, A-C President

Multi-Million Dollar Expansion Program Backs A-C Confidence in Future

"The past year has seen a new high level of peacetime production *and* delivery of goods set by our Company. This record has resulted from: 1) large backlogs; 2) continued strong demand in practically all lines; 3) increased, and improved utilization of facilities. With steady improvement in availability and quality of materials and better reserve of skilled workers, we look forward to the balance of 1949 confident that even greater quantities of A-C products will be built and delivered on schedule, to help you meet the continuing power demands of the nation."
—Walter Geist

W. C. Johnson
Exec. V.P.

COUPLED WITH THE LARGEST and finest production facilities in A-C history, go many new and improved, as well as existing, power and electrical designs.

This past year, in addition to completing a huge expansion program—including new building, new equipment, streamlined facilities—we achieved record output in Steam and Hydraulic Turbo-Generating units, Power Transformers, Generators, Condensers, Voltage Regulators, Power Plant Motors, and other lines.

Many specific developments, from completion of preferred Standard Turbines 11,500 kw through 60,000 kw . . . to redesign of the "Safety-Circle" motor line were accomplished. Notable among these: advances in generator hydrogen cooling; testing and marketing of *tube-type* TEFC motors; expansion of motor starter lines; development on gas turbine; standardization on power and distribution transformers and Load Ratio Control for unit substations; extension of circuit breaker ratings to 3,500,000 kva; and organization of "Certified Service Shops" throughout U.S.

J. L. Singleton
V.P., Dir. Sales

★ ★ ★

A confident outlook is an integral part of Allis-Chalmers' philosophy of doing business. Despite difficulties . . . in materials, for example, obtaining the right kind and a steady supply . . . we have been able to deliver critical equipment, for the most part, on time.

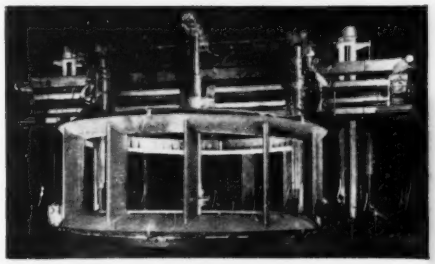
We have added to and perfected our research and test facilities; are set up to tackle new problems as they arise. We have reinforced both our field sales and service organizations.

Add to all of this one of the widest lines of power and electrical equipment, 102 years' of service to industry, over 65 years' electrical . . . and you can see why many Utilities specify "A-C" as their regular source of equipment supply! Sales offices in all principal cities. ALLIS-CHALMERS, 932A S. 70TH ST., MILWAUKEE 1, WIS.

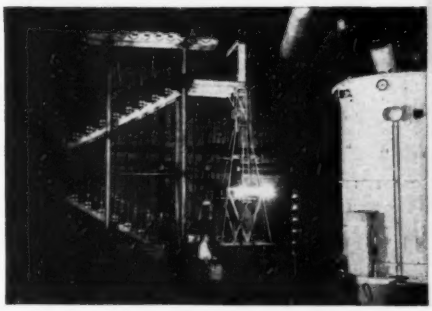
Safety-Circle is an Allis-Chalmers Trademark

A2712

ALLIS-CHALMERS



GIANT 40-FT BORING MILL, one of largest in America

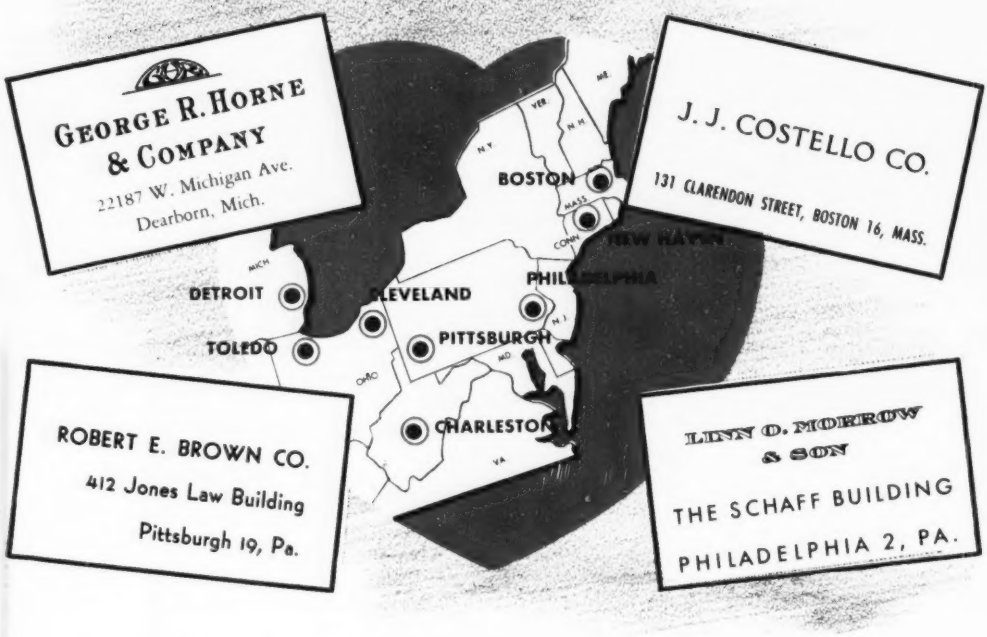


3,000,000 VOLT high v. transformer test laboratory

MAIN ERECTING SHOP—1250 ft long, 4 stories high

SALES "KNOW-HOW"

Today's most important ingredient . . .



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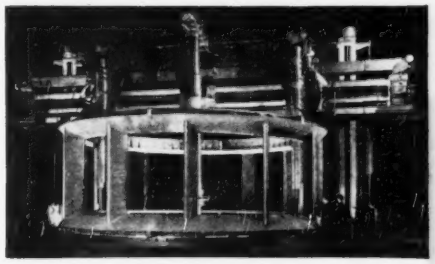
ALLIS-CHALMERS



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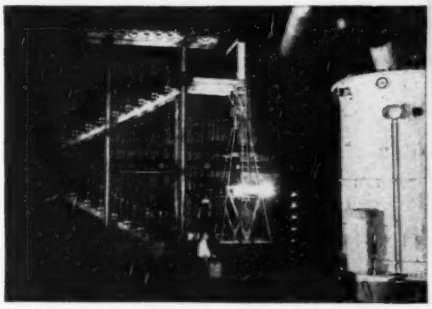

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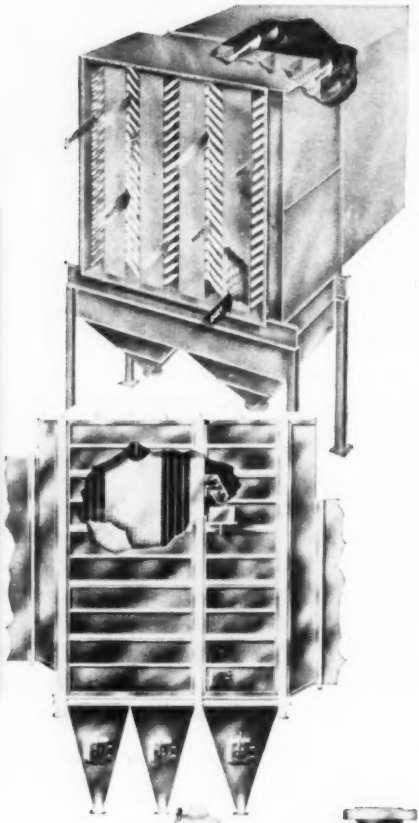
Pacing INDUSTRY



Progress requires continuous research and development to find better ways of making better products.

An excellent example of this continuous development is the Aerotec tube that forms the basis of the cyclonic type, multiple tube Aerotec Design 3 RAS Collector.

Originally developed as a brazed steel tube, this unit went through a series of evolutions that finally resulted in the highly efficient permanent molded aluminum tube used today. Years of research by men who had spent a lifetime in the field made it possible, and this same background of personnel has been behind the many other developments of The Aerotec Corporation.

The Aerotec Electrical Precipitator has gone one step further in the art of dust collection. Pocket-design collecting electrodes now reduce the possibility of re-entrainment of dust particles. This pocket design has changed the conception of particle size limitation on electrical dust precipitation.

For the oil industry, Aerotec manufactures a new and unique oil and gas separator. The Aerotec Integral Collector for industrial applications rounds out the service of Aerotec in that field. A packaged unit, this highly efficient collector offers the advantages of no pressure build-up, yet is as efficient as impingement type filters.

In the field of controls, valves and switches, Aerotec's war record is reflected in many of the controls now applied to aircraft. From pressure switches to float valves, Aerotec units are designed to a precision and quality that assure a long maintenance-free life.

Our Project and Sales Engineers will gladly help you solve your problems.

Project and Sales Engineers

THE THERMIX CORPORATION

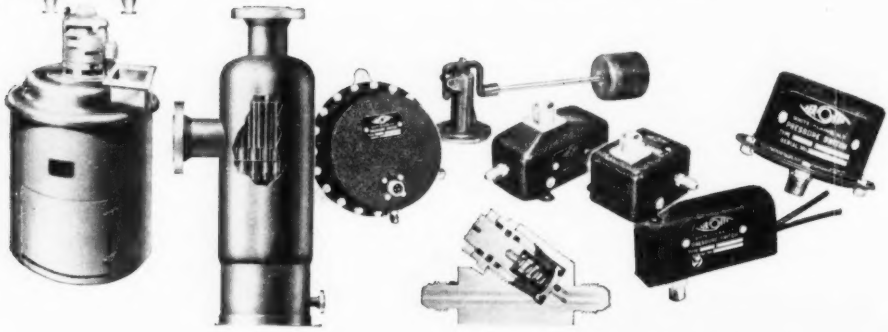
First National Bank Building **Greenwich, Conn.**

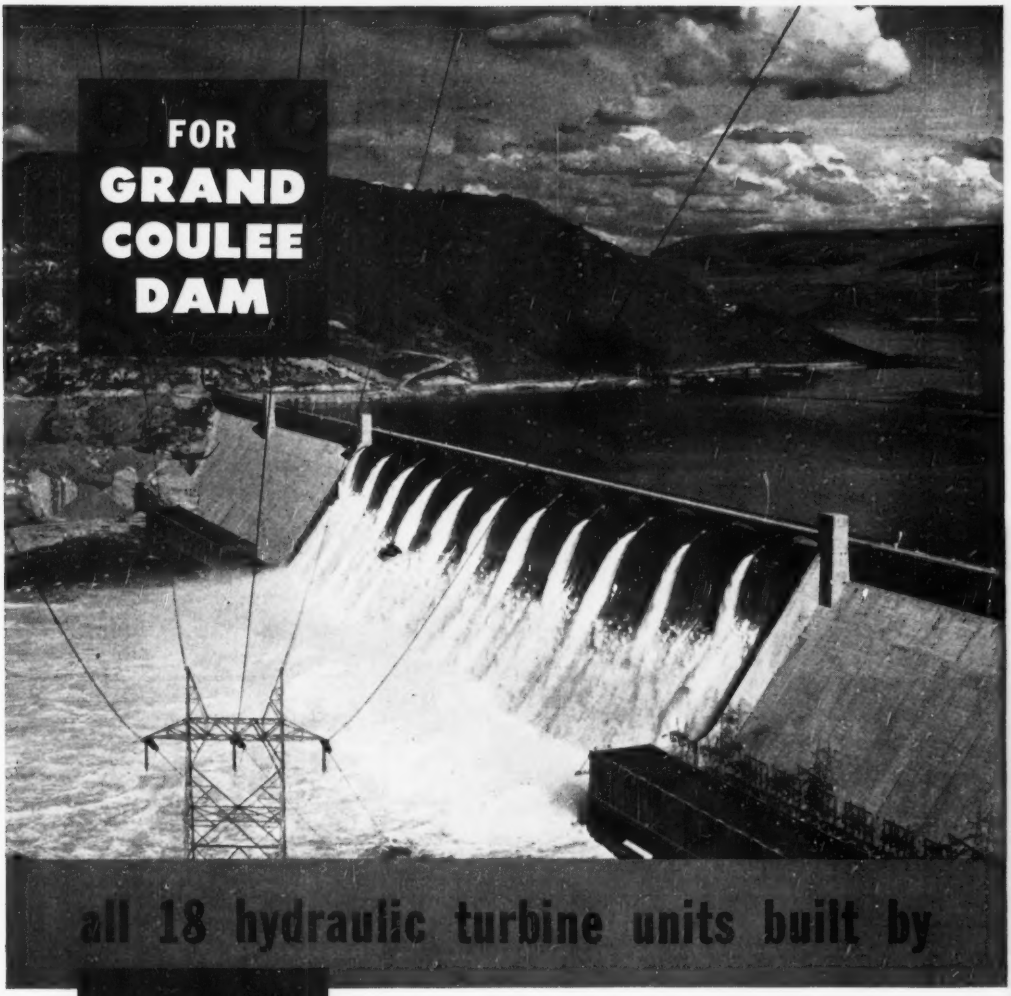
(Offices in 28 Principal Cities)

Canadian Representative: **T. C. CHOWN, LTD.**, 1440 St. Catherine St. W., Montreal 25, Quebec

THE AEROTEC CORPORATION

GREENWICH, CONN.





NEWPORT NEWS

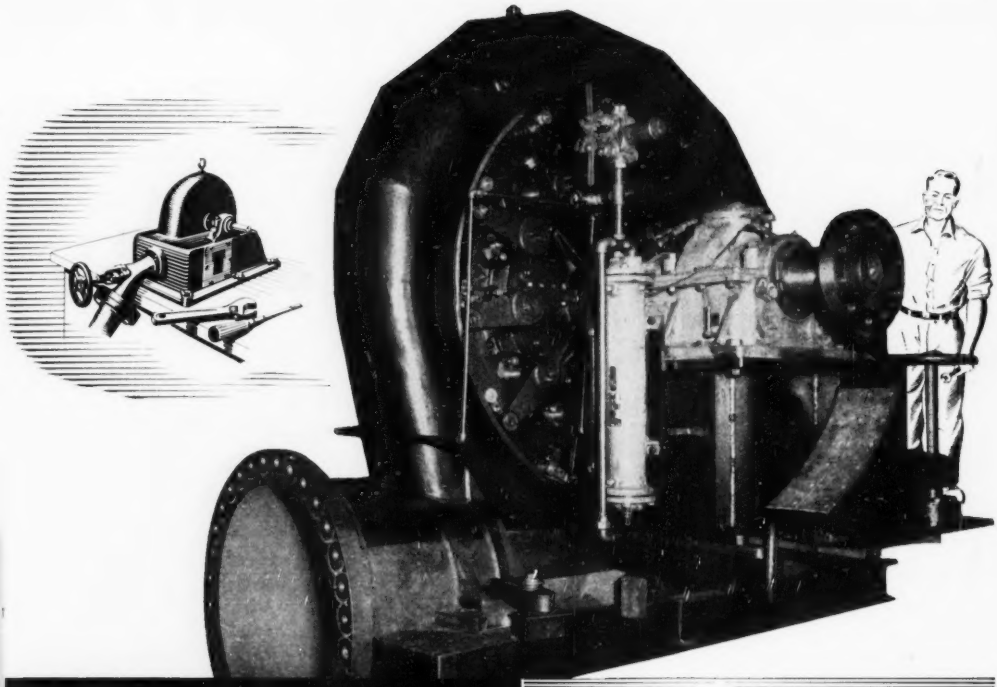
Contracts for all 18 turbines for Grand Coulee Dam, which are the most powerful hydro-electric units ever built, have been awarded to Newport News. The nine units for the west powerhouse rated at 150,000 h.p. each have consistently produced up to 167,500 h.p. each during their first full year of operation. The nine units in the east powerhouse will each be rated at 165,000 h.p.

Newport News built its first hydraulic turbine in 1921. Since then contracts received aggregate a rated output of 6,118,000 h.p. The engineering efficiency and workmanship of these units have been proven by actual performance in many of the world's great power developments.

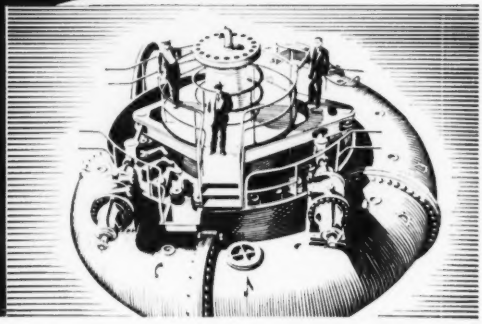
NEWPORT NEWS

Shipbuilding and Dry Dock Company

NEWPORT NEWS, VA.



BALDWIN
HYDRAULIC TURBINES
All sizes for all applications



No matter how large or how small a water-power development you are considering—Baldwin can provide a turbine unit to fit!

OUTPUTS. Baldwin is equipped to build turbines in a range from small fractional horsepower water motors up to the largest units that can be shipped.

HEADS. Baldwin can furnish turbines for any required head—from the highest to the lowest.

TYPES provided by the line include impulse, propeller, Francis, and Kaplan (adjustable blade) units.

Baldwin offers a century of sound, practical engineering experience gained in hundreds of previous jobs . . . experience that has helped contribute to the technical progress of an industry, and helped produce some of the most advanced developments in hydraulic turbine equipment.

For a concise, comprehensive picture of the Baldwin turbine line, ask for Bulletin 252. The Baldwin Locomotive Works, Philadelphia 42, Pa. The Pelton Water Wheel Co., 2929 Nineteenth Street, San Francisco, Calif.

The Baldwin Locomotive Works, Philadelphia 42, Pa., U. S. A. Offices: Boston, New York, Philadelphia, Houston, St. Louis, Chicago, Cleveland, Pittsburgh, San Francisco, Seattle, Washington. In Canada: Baldwin Locomotive Works of Canada, Ltd., Toronto, Ontario.

BLW THE BALDWIN GROUP

BALDWIN
HYDRAULIC TURBINES

IMPULSE PROPELLER FRANCIS KAPLAN

CONGRATULATIONS to the STAFF of the ELECTRICAL WORLD on the OCCASION of its 75th ANNIVERSARY!

Lightning Calculator

THE past 75 years have witnessed remarkable progress in the tabulation and analysis of figures for business use.

The simple, school-room method of calculation has given way to a complex variety of electro-mechanical devices. Tedious tabulations that once would have taken months to finish are now completed in a matter of days, or even hours. For example . . .

The Bill Frequency Analyzer

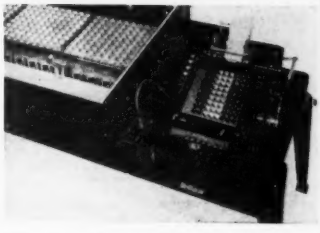
Today, utilities no longer need rely on their own clerical staffs to analyze bills for customers' usage data.

The Bill Frequency Analyzer—developed by the Recording and Statistical Corporation — analyzes as many as 200,000 bills each day.

It gives utility rate engineers customers' usage data in ½ the time . . . at ½ the usual cost of having it compiled in their own offices.

Other high-speed electro-mechanical equipment in our offices—operated by trained personnel—is at your service just as it is for leading publishers, advertising agencies, the automobile industry, the banking and insurance fields, and ever so many of America's large and small concerns.

We shall be glad to discuss how you may benefit from our statistical services. No obligation, of course. Just address our main office.



This is a Bill Frequency Analyzer on which we can analyze customers' usage data for you at ½ the usual cost of having it compiled in your own offices. SEND FOR FREE BOOKLET—*The One Step Method of Bill Analysis* **which** tells how you may save time and **money.**

Recording and Statistical Corporation

100 SIXTH AVENUE, NEW YORK 13, N. Y.

CHICAGO • BOSTON • DETROIT • MONTREAL • TORONTO

For Outboards, Too . . .

MALLORY TUNGSTEN CONTACTS

Guarantee Longer Life

In a modern outboard motor the contacts in the magneto-type ignition system make and break *4,000 times a minute!*

Contacts have to be tough to stand that gaff. Those contacts have to be made of material with extraordinary wear-resistance.

The tough, interlocking grain structure of Mallory Tungsten Contacts—that keeps down erosion throughout long periods of service—is the result of the most rigid processing controls. Mallory Tungsten Contacts—like all Mallory Contacts—are manufactured to a most exacting standard.

What's Your Problem?

Mallory makes contacts for every need—from those used in tiny motors for electric razors to activating street lighting systems. Mallory has designed so many types that even if you have an unusual problem, you'll probably find a standard Mallory Contact to handle it. If not—Mallory engineers are equipped to develop one for you. Consult them now.

For all kinds of contact materials and service, you can't beat Mallory as a dependable, experienced source.

In Canada, Made and Sold by Johnson, Matthey & Mallory Ltd., 110 Industry St., Toronto 15, Ontario.

Electrical Contacts and Contact Assemblies

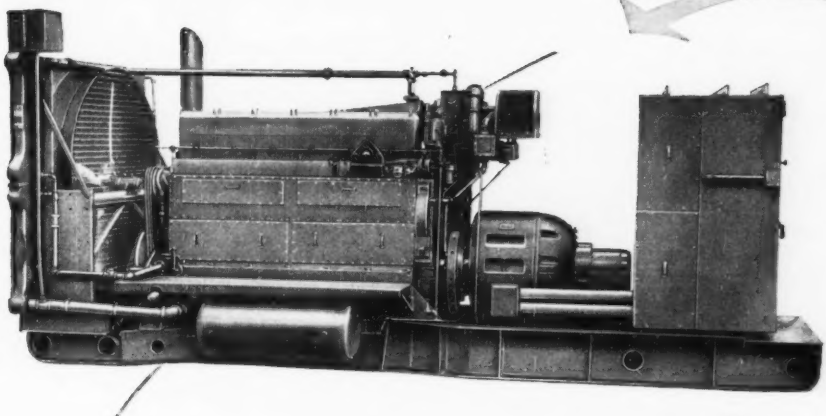
P. R. MALLORY & CO. Inc.

MALLORY

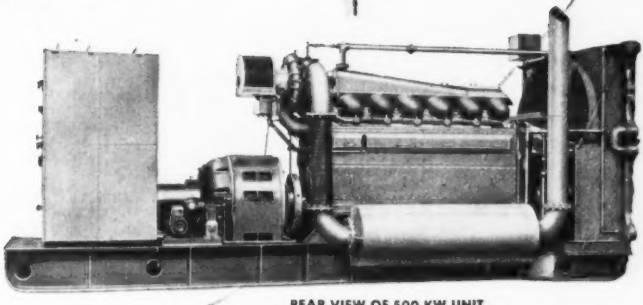
P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA

SERVING INDUSTRY WITH

Capacitors — Rectifiers
Contacts — Switches
Controls — Vibrators
Power Supplies
Resistance Welding Materials



Answers Utilities' demands for portable, dependable power



REAR VIEW OF 500 KW UNIT

EFFICIENCY PLUS ECONOMY

LOW FUEL CONSUMPTION results from efficient design of combustion chamber, valve mechanism and fuel injection system.

INSTANTANEOUS STARTING is assured by simple starting valve which admits air through distributor. The distributor, in turn, admits air at timed intervals to each cylinder.

DUST-TIGHT COVERS completely enclose all wearing parts, but are easily removed for inspection.

LUBRICATION is completely automatic force feed, resulting in exceptionally low maintenance.

EVERY PART is designed with ample strength for maximum rigidity with minimum weight assuring long service life.

Newest of the CP package units, this 500 kw CP Turbo-charged* Diesel or Dual-Fuel-Electric Engine Generator Set is another outstanding product of Chicago Pneumatic's thirty-four years' experience in engine building.

Designed for continuous, medium-speed, heavy-duty service, it is ideal on stub lines to avoid interrupted service or power drop. On temporary line repairs it can be installed at cut-out points.

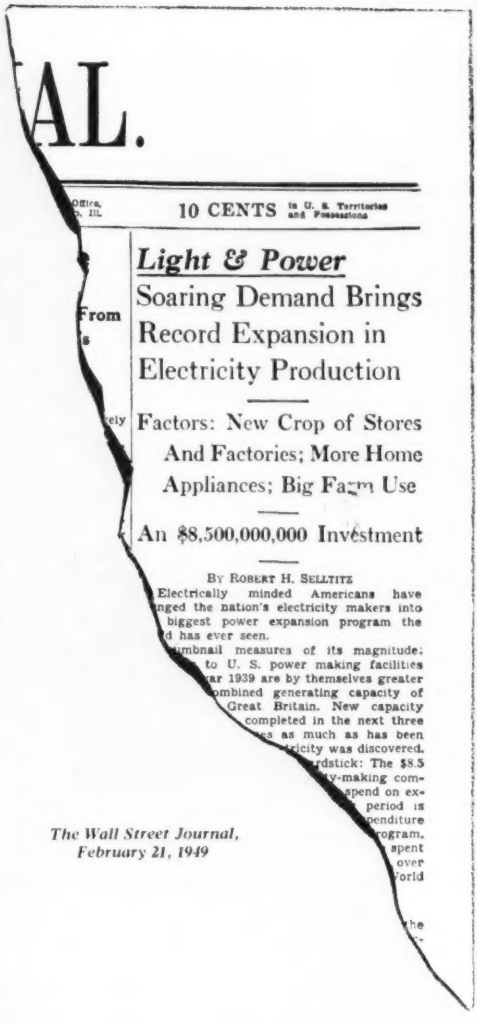
Furnished complete with piping, wiring, and all accessories. Ready for immediate installation, it can be set up quickly and easily, with minimum expense. Write for complete information.

*BUILT UNDER ELLIOTT-BUCHI LICENSE

CHICAGO PNEUMATIC TOOL COMPANY

General Offices: 8 East 44th Street, New York 17, N. Y.

PNEUMATIC TOOLS • AIR COMPRESSORS • ELECTRIC TOOLS • DIESEL ENGINES
ROCK DRILLS • HYDRAULIC TOOLS • VACUUM PUMPS • AVIATION ACCESSORIES



AL.

Office, . Ill. 10 CENTS In U. S. Territories and Possessions

Light & Power

Soaring Demand Brings Record Expansion in Electricity Production

From is

ely Factors: New Crop of Stores And Factories; More Home Appliances; Big Farm Use

An $8,500,000,000 Investment

By Robert H. Selltitz

Electrically minded Americans have nged the nation's electricity makers into biggest power expansion program the d has ever seen.

umbnail measures of its magnitude: to U. S. power making facilities ar 1939 are by themselves greater mbined generating capacity of Great Britain. New capacity completed in the next three s as much as has been tricity was discovered. rdstick: The $8.5 y-making com- spend on ex- period is penditure rogram, spent over orld he

The Wall Street Journal, February 21, 1949

10%

The power generating facilities designed and constructed by Stone & Webster Engineering Corporation through the years total over 6,000,000 kilowatts, equivalent to one-tenth of the total generating capacity of all electrical utilities in the United States.

Work of the Corporation currently in progress for leaders in the industrial and public utilities field in all parts of the country will increase this total over 2,000,000 kilowatts.

STONE & WEBSTER ENGINEERING CORPORATION

A SUBSIDIARY OF STONE & WEBSTER, INC.

550,000-kw Philip Sporn Plant now under construction

We've doubled our capacity . . . and more power's on the way

Every year since the war, customers of American Gas and Electric System companies have made greater demands for power. Every year, the demands have been met in full.

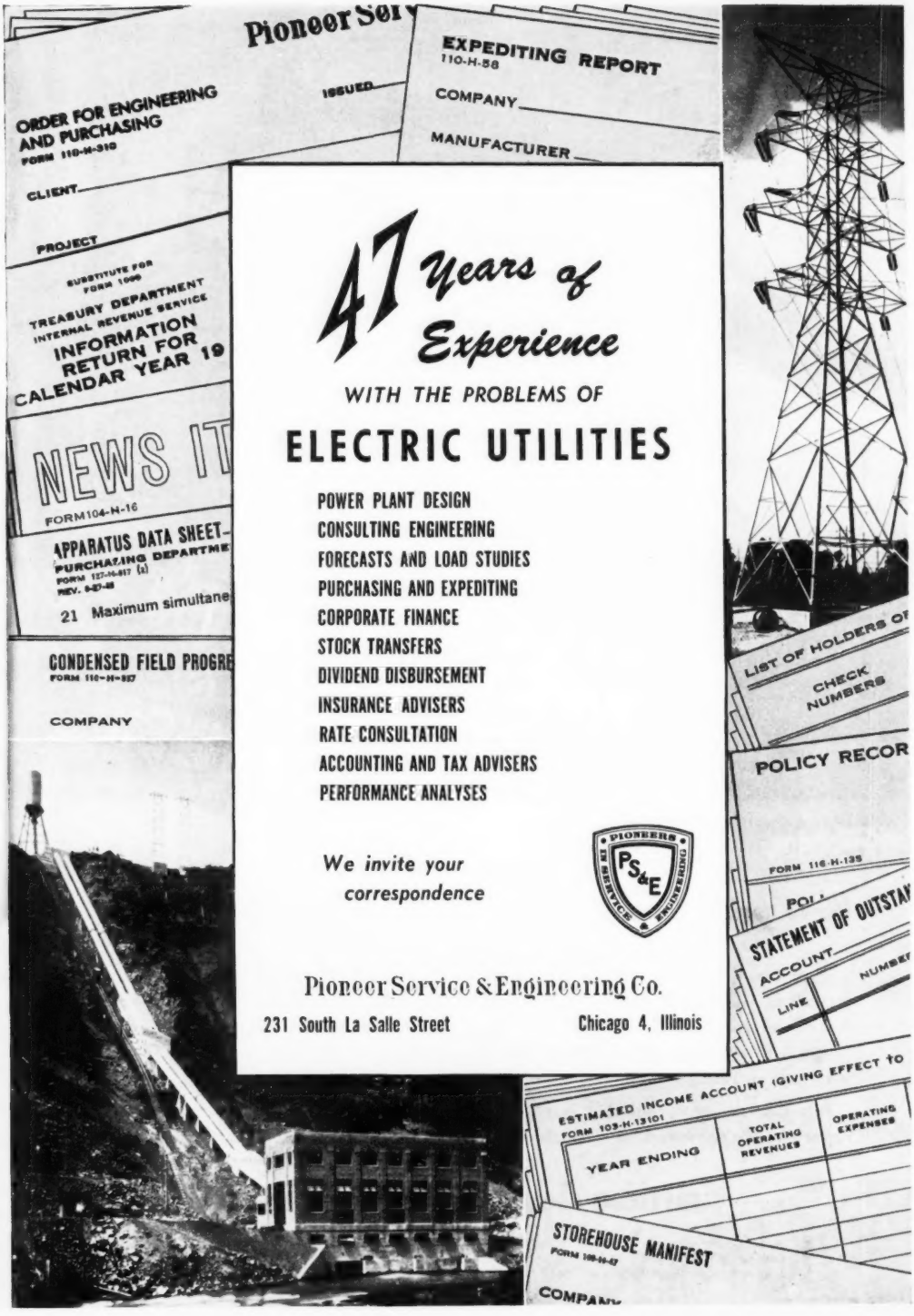
Since 1939 we've doubled our plant capacity. We're spending $305,000,000 between 1947 and '51 to add new power facilities. Plants totaling 1,106,000 horsepower are now being built. All will be completed by 1951, two even sooner.

These plants are further assurance to our million customers that we'll continue to supply power enough for all.

American Gas and Electric Company

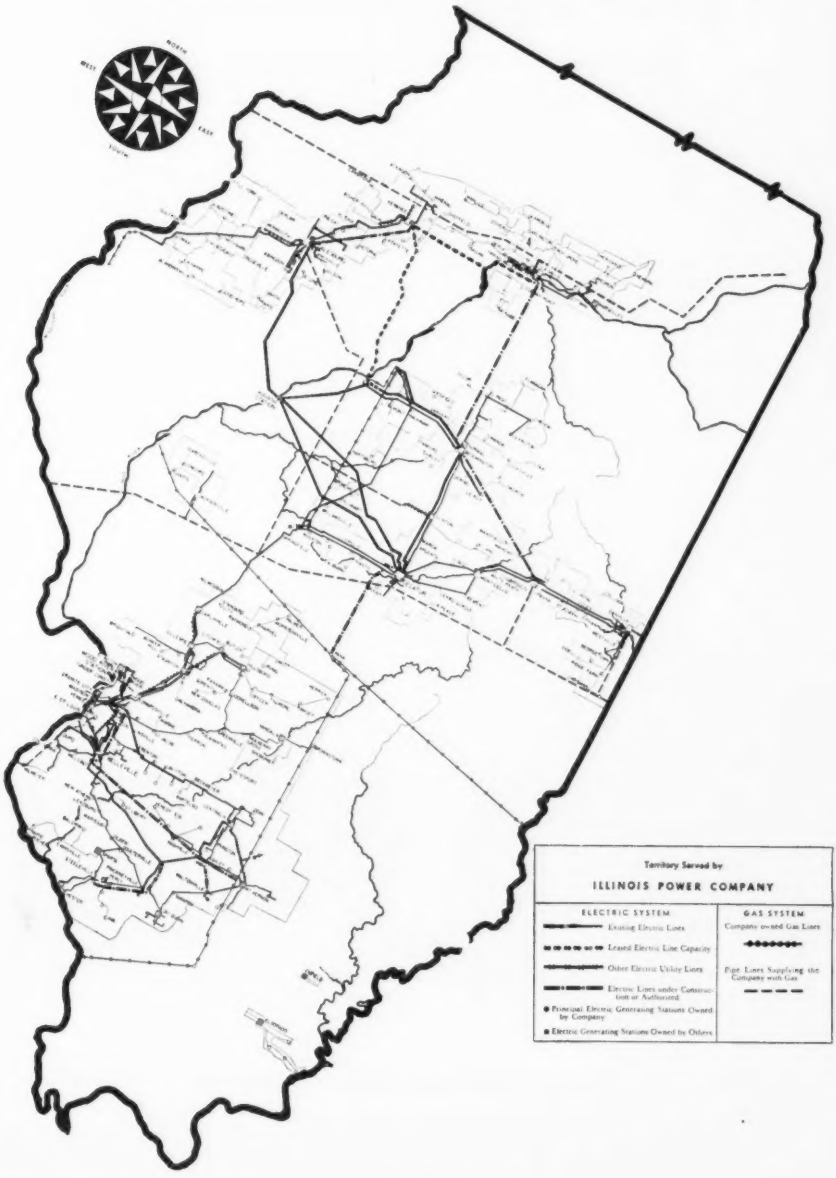
Appalachian Electric Power Company
Indiana & Michigan Electric Company
Kentucky and West Virginia Power Co., Inc.
Kingsport Utilities, Inc.
The Ohio Power Company
Wheeling Electric Company

Citizens Heat, Light and Power Company


Pioneer Ser
ORDER FOR ENGINEERING AND PURCHASING
FORM 110-H-910
ISSUED
CLIENT
PROJECT
EXPEDITING REPORT
110-H-58
COMPANY
MANUFACTURER
SUBSTITUTE FOR FORM 1099
TREASURY DEPARTMENT
INTERNAL REVENUE SERVICE
INFORMATION RETURN FOR CALENDAR YEAR 19
NEWS IT
FORM104-H-16
APPARATUS DATA SHEET-
PURCHASING DEPARTME
21 Maximum simultane
CONDENSED FIELD PROGRE
FORM 110-H-927
COMPANY
47 Years of Experience
WITH THE PROBLEMS OF
ELECTRIC UTILITIES
POWER PLANT DESIGN
CONSULTING ENGINEERING
FORECASTS AND LOAD STUDIES
PURCHASING AND EXPEDITING
CORPORATE FINANCE
STOCK TRANSFERS
DIVIDEND DISBURSEMENT
INSURANCE ADVISERS
RATE CONSULTATION
ACCOUNTING AND TAX ADVISERS
PERFORMANCE ANALYSES
We invite your correspondence
PIONEERS IN SERVICE ENGINEERING
PS&E
Pioneer Service & Engineering Co.
231 South La Salle Street
Chicago 4, Illinois
LIST OF HOLDERS OF
CHECK NUMBERS
POLICY RECOR
FORM 110-H-135
STATEMENT OF OUTSTA
ACCOUNT
LINE
ESTIMATED INCOME ACCOUNT (GIVING EFFECT TO
FORM 103-H-13101
YEAR ENDING
TOTAL OPERATING REVENUES
OPERATING EXPENSES
STOREHOUSE MANIFEST
FORM 108-H-47

ILLINOIS POWER COMPANY

...SERVES A WIDELY DIVERSIFIED AND CONSISTENTLY PROSPEROUS SECTION OF ILLINOIS.


Territory Served by
ILLINOIS POWER COMPANY
ELECTRIC SYSTEM
Existing Electric Lines
Leased Electric Line Capacity
Other Electric Utility Lines
Electric Lines under Construction or Authorized
Principal Electric Generating Stations Owned by Company
Electric Generating Stations Owned by Others
GAS SYSTEM
Company-owned Gas Lines
Pipe Lines Supplying the Company with Gas

JACKSON & MORELAND

ENGINEERS AND CONSULTANTS

BOSTON • NEW YORK

DESIGN AND SUPERVISION
OF CONSTRUCTION

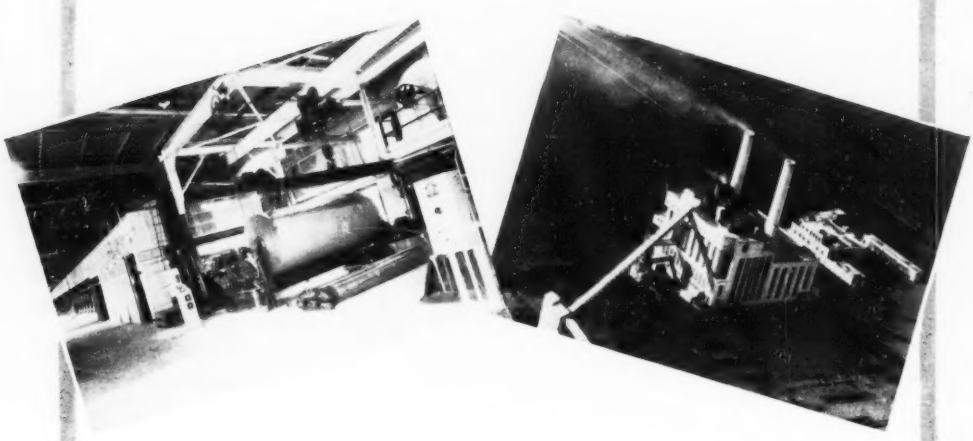
REPORTS

EXAMINATIONS

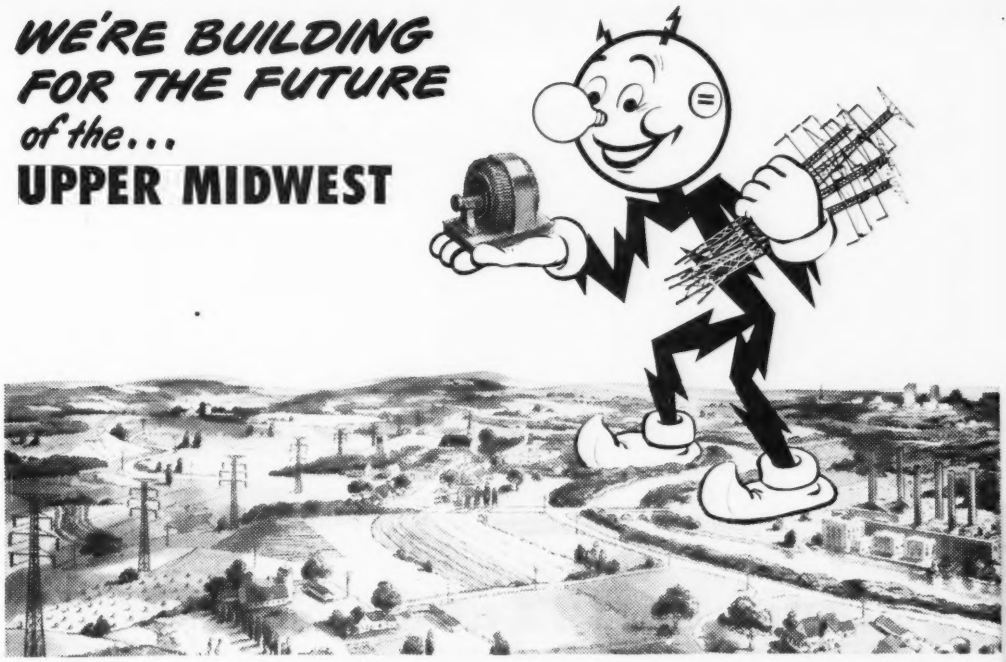
APPRAISALS

MACHINE DESIGN

TECHNICAL PUBLICATIONS



WE'RE BUILDING FOR THE FUTURE of the... UPPER MIDWEST



Northern States Power Company to Spend $155,000,000

The Upper Midwest is growing. Population is increasing. Business and industries are increasing. Hand in hand with this growth in population and business, Northern States Power Company has experienced a tremendous increase in the demand for electric power. Within the next five years our Company expects the demand for electricity will increase 50%.

Business, industry, as well as homes and farms, cannot function unless there is an adequate and dependable supply of electric power. If, as we expect, the demand for electricity increases 50% in this period, the Northern States Power Company must be ready to meet this demand if we are properly to serve the public. This entails long-range planning and a tremendous amount of building.

WHAT ARE WE DOING ABOUT IT?

356,000 Kilowatts of New Generating Capacity to be Installed

The program involves the construction of new plants and the installation of new generating units throughout our territory. The following table indicates the year these new generators are scheduled to go into service.

Year	Generating Capacity
1947	27,000 Kilowatts
1948	58,000 "
1949	104,500 "
1950	106,500 "
1951	60,000 "
TOTAL	356,000 Kilowatts

NEW POWER PLANTS

In 1947 the Northern States Power Company undertook a five-year program to increase its generating capacity by 356,000 kilowatts. Because of the delay in PROCURING STEAM TURBO-GENERATORS, 30 Diesel generators of approximately 1,000 kilowatt capacity each were ordered for emergency service. Twenty-seven of these generators are now in operation.

MISCELLANEOUS CONSTRUCTION

This five-year construction program, besides generating plants and transmission lines, includes the construction of some 20 new distribution substations and the reconstruction and increase in capacity of approximately 300 other stations. It also includes the rebuilding and rewiring of transmission lines throughout our entire system.

The future prosperity of Northern States Power Company is firmly linked with the future prosperity of the Upper Midwest. That future, to a large extent, depends upon a sufficient supply of electric power available at all times. Only by careful and skillful planning and building today can an adequate supply of electric power be available for this area in the years to come.

We are proud of the fact that our Company has always provided ample power for the people of the Upper Midwest. We have at all times had sufficient electric power to take care of every customer who applied for service. No bona fide request for power has ever been turned down despite the tremendously increased demand through two World Wars and despite unparalleled shortages of materials and labor.

You as a customer, whether you are a businessman, industrialist, farmer, or homemaker, can look forward to the future with confidence as far as your electric service is concerned—and we wish you to know these facts.

New Construction to Cost $155,000,000

This five-year construction program undertaken in 1947 includes the installation of additional generating capacity, the construction of some twenty new distribution stations, the reconstruction and increase in capacity of approximately 300 stations, and the rehabilitation and reconductoring of transmission lines throughout our entire system which serves some 606 communities in 5 states.

The cost of this five-year program involves an expenditure of approximately $155,000,000.

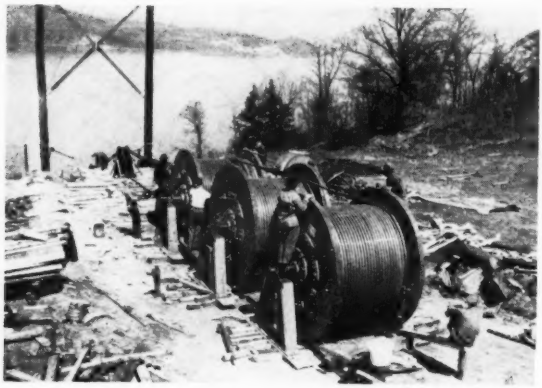
Upon completion of this program the capacity of our system will have been increased approximately 65% to provide for requirements and for reserve capacity.

These additions to our interconnected system mean that we will have created a power pool of almost a million kilowatts —in order to bring MORE and BETTER electric service to more and more people.

NORTHERN STATES POWER COMPANY

Reproduction of a newspaper advertisement recently published in all communities served by Northern States Power Company

FIRST OILOSTATIC SUBMARINE CABLE SOLVES HUDSON RIVER CROSSING



REEL SET UP

Three 3,675-foot continuous cable lengths were pulled simultaneously into 6-inch pipe on the river bed.

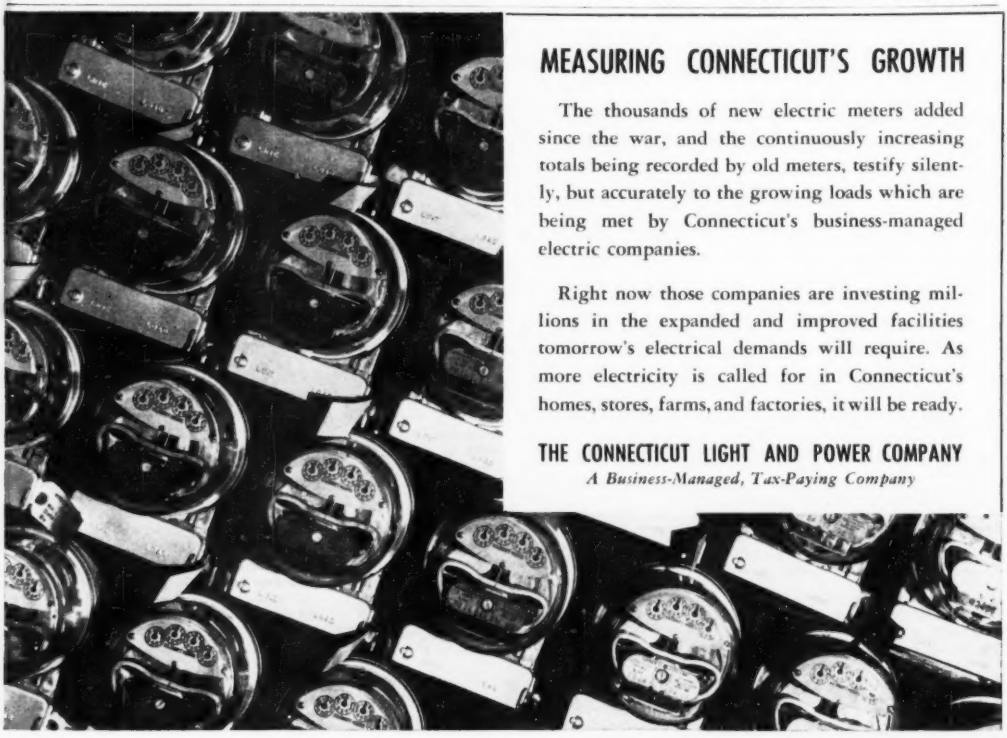
To reinforce Central Hudson's transmission system, the first application of Oilostatic pipe-type cable to submarine service was made during 1948 where it carries a new 110-kv. transmission circuit under the Hudson River.

The submarine cable, with its transmission line and substation connections, is part of Central Hudson's long range plan to better serve its customers.

CENTRAL HUDSON GAS & ELECTRIC CORPORATION

"Serving the Central Hudson Valley"

GENERAL OFFICES — POUGHKEEPSIE, N. Y.



MEASURING CONNECTICUT'S GROWTH

The thousands of new electric meters added since the war, and the continuously increasing totals being recorded by old meters, testify silently, but accurately to the growing loads which are being met by Connecticut's business-managed electric companies.

Right now those companies are investing millions in the expanded and improved facilities tomorrow's electrical demands will require. As more electricity is called for in Connecticut's homes, stores, farms, and factories, it will be ready.

THE CONNECTICUT LIGHT AND POWER COMPANY

A Business-Managed, Tax-Paying Company

In saluting "Electrical World" on its seventy-fifth anniversary of service to the electric utility industry, Public Service Electric and Gas Company wishes this outstanding publication continued success.

Here in New Jersey, this business-managed utility has grown apace with a great state. Starting in 1903 with a generating capacity of 36,067 kilowatts, the Public Service electric system has developed to its present capacity of 1,411,150 kilowatts. Through the years, New Jersey has grown also, to the point where it stands today as sixth in the nation in the total value of manufactured products.

Just as "Electrical World" will continue to grow with the electric utility industry, so will Public Service keep step with the progress of New Jersey.

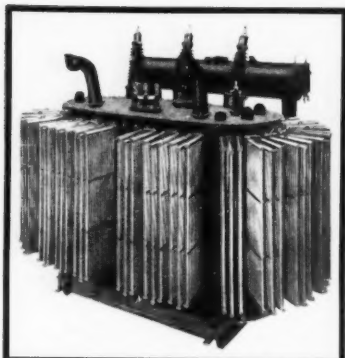
As George H. Blake, President of Public Service Electric and Gas Company, said recently:

> "We believe that the progress of New Jersey, in fields of economics, industry, commerce and community welfare, concerns Public Service directly. Our future is tied up with the future of New Jersey".

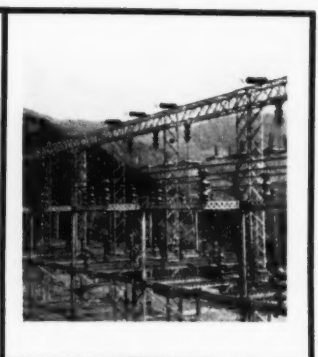
PUBLIC SERVICE

Public Servant of a Great State

A-162-49



PENNSYLVANIA TRANSFORMER COMPANY



ELECTRIC POWER EQUIPMENT CORPORATION

Bra Bon

Electric Company

SALES REPRESENTATIVES SINCE 1930

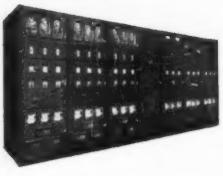
In a territory including Virginia, Pennsylvania, New Jersey, Delaware and Maryland—Bra Bon Electric Company represents these four leading manufacturers: Pennsylvania Transformer . . . Elpeco . . . Roller-Smith . . . and Matthews. Their products are illustrated.

Bra Bon's sales and service staff is constantly circulating in the utility field, rendering technical information concerning application of the products handled. You are assured of competent advice as every member of our staff is capable of solving your most difficult problems. We feel we have definitely contributed to the growth of the electrical industry.

BRA BON ELECTRIC COMPANY

Lewis Tower Bldg. • 15th & Locust Sts., Phila., Pa.

ROLLER-SMITH



W. N. MATTHEWS CORPORATION

Free Enterprise?

Those two words have sure been kicked around lately, but now it's time for a little straight thinking. To me, free enterprise means a good day's pay for a good day's work—fair treatment for the man who uses the tools and for the man who buys 'em—I'm for it, with or without capital letters.

I like job security—the kind of security that comes from knowing I'm good at my job. I want to know that I can go just as far as my brains and hands will carry me, and I want my kids to have the same chance I have. I want to plan my own future and make my plans come true.

I know how good we have things here right now, and I want to help make them even better. But I want to be sure any new ideas that get thrown into the pot are strictly native-born, and I want to have a hand in any tinkering that's to be done with the economic machinery.

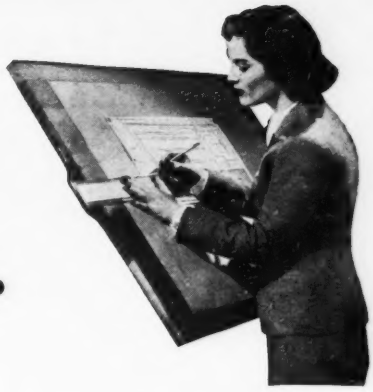
That's what free enterprise means to me, Mister, and I want it kept just that way!

WISCONSIN

Public Service

CORPORATION

When you need copies...



You need OZALID!

Duplicate in seconds! Simply put your original against a sheet of Ozalid material and feed into the Ozalid print-making machine. An intermediate step is necessary only with absolutely opaque originals.

Change in seconds! Make alterations or additions on your translucent Ozaprint... transfer title blocks or even whole sections... then you can use the changed print as a master!

Combine in seconds! Make prints of your material on transparent Ozalid film, overlay them on a sheet of Ozalid material (paper, cloth, foil, or film), feed into the Ozalid machine for a composite print in 25 seconds!

Replace in seconds! Use any translucent Ozalid print for a duplicate master. Make shop or field prints on Ozaplastic. Clean with a damp cloth.

Color Code in seconds! Ozalid materials offer black, blue, red, or sepia lines on white or tinted backgrounds. Light, standard, and heavyweight papers are available for any job.

Anyone can make prints with Ozalid in seconds! Reproduction can be made any length and almost any width. All Ozaprints are made in the same manner – all are delivered dry, positive, and ready to use.

Write on your letterhead for a FREE booklet that tells the full Ozalid story. Or consult your classified directory for local distributor.

Don't copy... use OZALID!

Johnson City, N. Y. Dept. 67
A Division of General Aniline & Film Corp.
"From Research to Reality"

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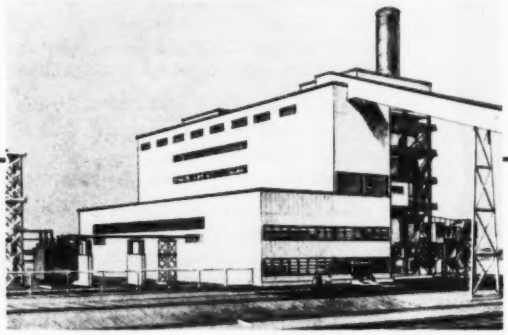

More Electricity For The Kansas City Area...

HAWTHORN STATION, a new 132,000-kilowatt base load plant, will serve an expanding industrial and agricultural area. Scheduled for completion by the summer of 1951, this new station will contain two 66,000-kilowatt units operated by steam produced in two semi-outdoor type high-pressure boilers rated at 650,000 pounds of steam per hour. HAWTHORN STATION will increase the available supply of electricity in the Kansas City area by 40 percent.

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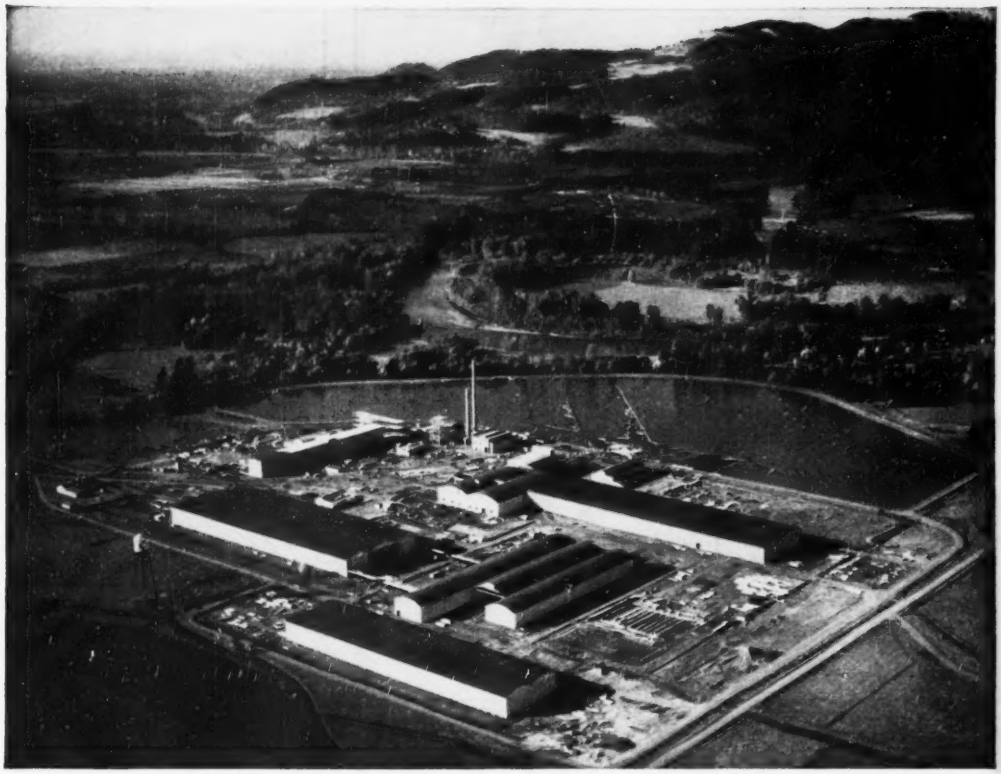

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The postwar demand for lumber, pulp board, and other wood products made it necessary for Weyerhaeuser Timber Company to expand its facilities to include a new development on the McKenzie River near Springfield, Oregon, strategically located for the direct delivery of logs from the timber-cutting areas.

We designed and constructed the power plant for the generation of the electrical power and process steam required by this new operation—a plant designed to permit the most efficient use of hogged-fuel consistent with logical capital expenditure.

As the process steam required by the sawmill and the pulp board plant can be used at comparatively low pressure, it is economical to produce higher pressure, steam, use it to generate electric power, and then for process requirements.

No matter what your project—a process plant, a public utility, a steel mill, a railroad terminal, an office building—we invite you to share our experience and facilities as designers, constructors and consulting engineers.

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Progress report on the
PORT WASHINGTON POWER PLANT
UNIT NO. 1
UNIT NO. 2
UNIT NO. 3
UNIT NO. 4
UNIT NO. 5
1935
1943
1948
1949
1951
ESTIMATED ULTIMATE INVESTMENT IN PORT WASHINGTON POWER PLANT
$47,500,000
The capacity of Port Washington Power Plant is being increased by 150 percent to insure the necessary reserves of power for the Company's system. Installation of the third 80,000 kilowatt unit at Port Washington is now nearing completion. The steel work is well under way for the fourth unit, and excavation has been started for the fifth unit. To obtain and install one of these large generating units requires three years or more.
These additions will bring the generating capacity at Port Washington up to 400,000 kilowatts and make it the largest power plant in Wisconsin.
The 240,000 kilowatts of capacity to be added, at an estimated cost of $32,500,000, will bring the total Port Washington Power Plant investment to approximately $47,500,000.
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The Electric Company • Public Service Building • Milwaukee, Wisconsin

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Shortly after this advertisement appeared, Unit No. 3 was placed in operation. Since then, construction work on Unit No. 4 has progressed considerably and all excavating for Unit No. 5 been completed

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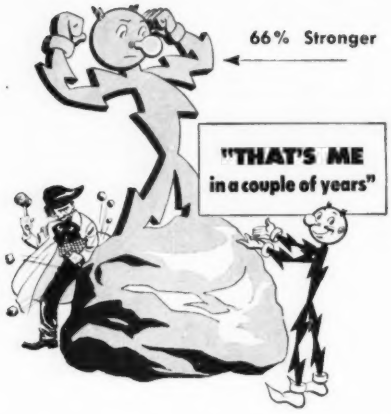

TO FULFILL its service responsibility, Wisconsin Power and Light Company is now engaged in a $30,000,000 construction program. Generating capacity will be increased by 66% in 1952.

This expansion is in anticipation of continued growth. Since 1939, the use of electricity per residential customer has nearly doubled, and the use of electricity per farm customer more than doubled.

Serving an area known as "The Heart of Wisconsin" which includes important industrial and trade centers and much of the State's richest farm lands, the Company is looking forward to continued growth in the demand for its services.

WISCONSIN POWER AND LIGHT COMPANY

122 West Washington Ave. ● Madison, Wisconsin

We're Helping to Make

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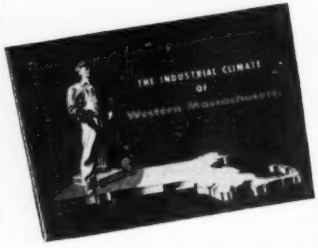
We have a lot of faith in the future of our neighborhood. Since early colonial times, men of action have peopled our valley. Here they have created the thriving industrial centers and rich farm sections that give our region a high degree of independence and stability.



We feel that there are such men today, seeking a place to locate their firms that offers these advantages. Because we believe our neighborhood has more than ever to offer, we are telling them what they need to know in a new booklet—"The Industrial Climate of Western Massachusetts."

WESTERN MASSACHUSETTS ELECTRIC COMPANY

WESTERN MASSACHUSETTS Electric COMPANY

An important ANNOUNCEMENT

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THE entire editorial content of this 75th anniversary edition, a record of the dynamic growth of the electrical industry, will be published at a later date in bound book from.

SUCH a book will be a mine of information for the industry newcomer and a constant reference for executives and operating men . . . telling the story of marketing electricity, of management, of organization, rate making, and financing . . . a comprehensive study covering the evolution of energy generation, distribution and utilization.

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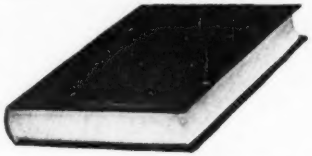
THE ELECTRIC POWER INDUSTRY



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Throughout the Pacific Northwest there's a shortage of electric power—except in southern Idaho, eastern Oregon, Utah and Montana. This is the area where business-managed electric companies have the responsibility for providing ample supplies of electricity. And they are fulfilling this responsibility—just as they have done for many years.

The remarkable new industrial development of southern Idaho is powered with ample supplies of electricity—phosphorus and fertilizer plants at Pocatello and Wendell—antimony at Stibnite—cobalt mining near Salmon—starch plants, lumber and agricultural processing at several locations.

This is one of few areas in the United States that today has enough electric power to be able to invite new industries—and is getting them.

Idaho Power Company has invested $28,000,000 since the war —and will invest an additional $50,000,000 in the next five years—in new plants and facilities.

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BACKED BY OVER HALF A CENTURY EXPERIENCE!

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Now, 60 years later, this pioneering company can recall with pride a long list of important contributions to the development of the now-great Inland Empire.

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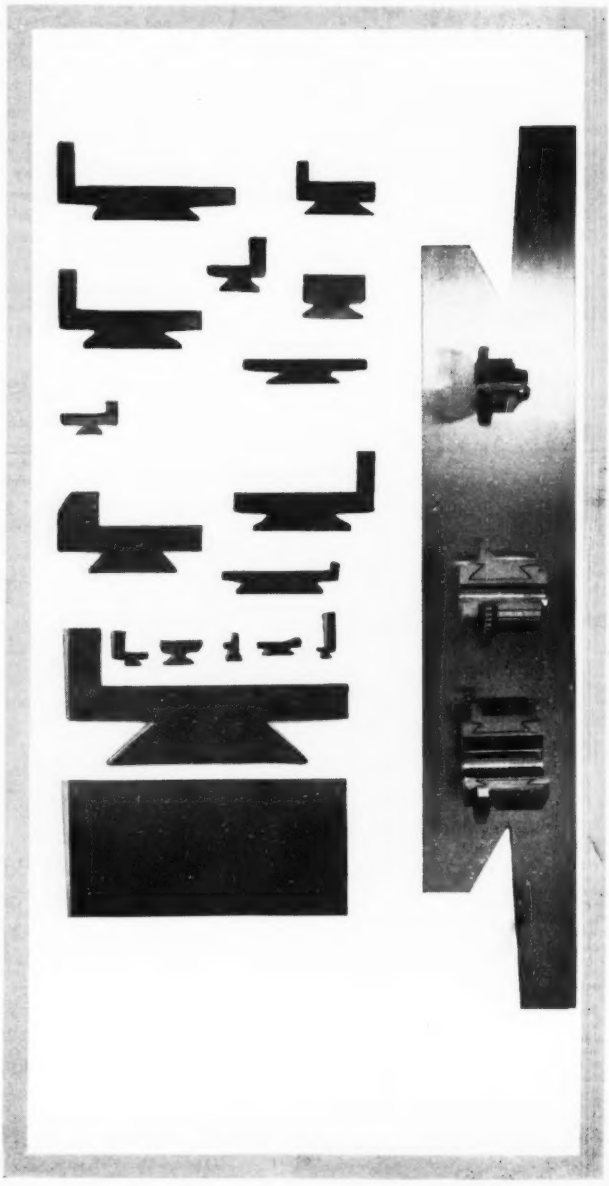
Revere's long manufacturing experience, and detailed understanding of the problems involved have been turned to excellent account by many manufacturers. We will gladly work with you in selecting the proper material for your commutators. Write Revere.



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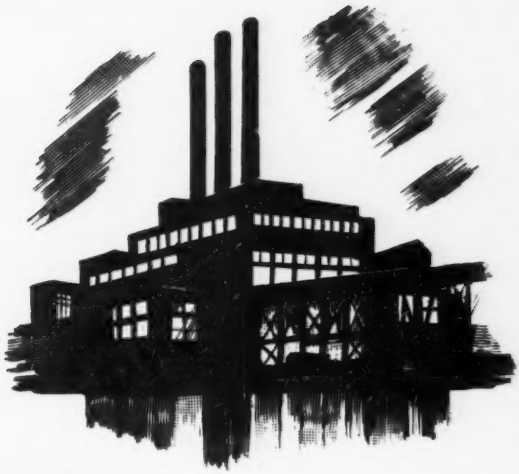


POWER STATIONS

STEAM POWER PLANT DEVELOPMENT

FUEL UTILIZATION AND STEAM GENERATION

STEAM TURBINES AND CONDENSERS

EXCITATION AND AUXILIARY SYSTEMS

Engineers and managements have always focused attention on the power plant – first on the thermal economy, later on reduction of initial cost and more recently also on reliability of operation. Consistent progress has been achieved in these aspects and in the simplification that comes from minimizing the variations in apparatus design and coordination. This pertains to everything from the fuel-handling and condensing-water systems, through the boiler and all its associated auxiliaries (including the electrically related excitation), to the turbines and condensers. The ensuing four articles were conceived and written to afford a logical recital of the significant stages of advancement in each bracket. Further, the papers tell what is so often hard to recall at a later date – what factors of inadequacy, limited reliability, economic pressure, etc brought about the progress embodied in the best of current practice.

PUSH OUT
AND FOLD

Contributors to Power Stations Section

George C. Daniels

Steam Power Plant Development

Mr. Daniels is chief mechanical engineer of The Commonwealth & Southern Corp, a Fellow of The American Society of Mechanical Engineers and chairman of the Prime Movers Committee of The Edison Electric Institute. He has designed numerous utility power plants in Michigan, Ohio, Indiana, Illinois and Pennsylvania and is the author of numerous papers in the ASME and in technical magazines.

R. T. Roberts

Fuel Utilization and Steam Generation

Mr. Roberts is division engineer in the Boiler Plant Equipment Division, Mechanical Engineering Department of the Consolidated Edison Co of New York, Inc and has been associated with power plant work for 30 years. He has to his credit several papers on boiler plants and cinder elimination in *Power Combustion* and *Power Generation*.

C. C. Whelchel

Steam Turbines and Condensers

Mr. Whelchel is Chief of the Division of Steam Engineering, Department of Engineering, Pacific Gas and Electric Co, San Francisco, California, and is a member of the Committee on Power Generation of AEIC and Prime Movers Committee of EEI. His experience covers manufacturing as well as power plant design, construction and operation with two of the large public utility companies in this country. At the present time his company is engaged in America's biggest power building program with almost one million kilowatts of new steam-electric generating capacity being added in the post-war period ending in 1951.

H. W. Eales

Excitation and Auxiliary Systems

Mr. Eales is consulting electrical engineer of Pioneer Service & Engineering Co, Chicago, Illinois. He has long been a member of the EEI Electrical Equipment Committee and the predecessor NELA Apparatus Committee; also of AEIC Committee on Electric Switching and Switchgear since its formation. Also, member earlier NELA Overhead Systems Committee, Power Systems Engineering Committee, Underground System Committee, and Inductive Coordination Committee. He has to his credit several papers on high voltage electric transmission lines.

Steam Power Plant Development

Traces introduction and cultivation of higher pressures, reheat, mercury cycle, slag-tap furnace, water-walls, pulverized fuel, bent-tube boilers, automatic controls, superposition, turning gears, forced circulation, gas turbine

ACHIEVEMENTS in steam power generation during 25 years have been due in no small measure to the activities of the Prime Movers Committee of the Edison Electric Institute, formerly the National Electric Light Association, whose published reports are a record of the step-by-step improvements both in this country and abroad, with detailed experience of troubles encountered and overcome. Those records have furnished the basis for this article in tracing the developments in the art of steam power generation, as practiced during the past 25 years.

Pressures Rise, Temperature Static

At the beginning of this period the Ferranti or regenerative cycle of bleeding steam from the turbine to heat the feedwater had been adopted, but steam pressures were still below 400 psi. Pressures were rapidly advanced to 1200 psi, but the steam temperatures were limited for many years to 725 F by the lack of economical materials to withstand higher temperatures. Very limited knowledge was available on the properties of steam at the higher pressures and temperatures or on the properties of metals at elevated temperatures. No generally accepted standards were available for pipe, fittings, or bolts for steam temperatures of 750 F above 250 psi. Boilers were rated in horsepower which was equivalent to 10 sq ft of heating surface for water-tube boilers, or 34½ lb evaporation from and at 212 F. They were built up to capacities of 2,000 hp, usually of the horizontal tubular type, and were well standardized. Several boilers were usually required per turbine, of which the largest single shaft unit in the mid-twenties was 35,000 kw. Refractory boiler settings were used, with the attendant heavy maintenance and frequent outages for repairs. At the bridge wall in the rear of underfeed stokers water-cooling from the boiler circulation was being tried out.

Establishment of the regenerative cycle was followed by development and use of air preheaters either to replace or reduce the size of economizers which were being supplied with feedwater at a much higher temperature than the 212 F that had been standard from the earliest state of the art. Incidentally, raising the temperature of the feedwater to the economizer eliminated to a marked degree the corrosion on the outside of the economizer tubes due to condensation of the sulphurous and sulphuric acids at former low temperatures and allowed use of steel economizer tubes instead of cast iron.

Auxiliaries Motor-driven

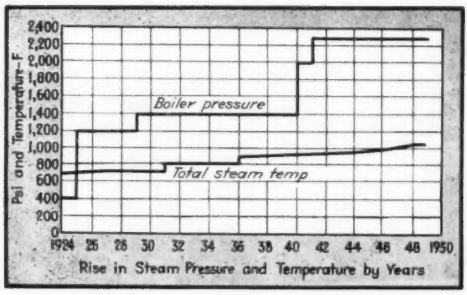
A definite trend had developed toward all motor-driven auxiliaries except boiler feed pumps, brought about by the high maintenance, inefficiency, and speed characteristics of auxiliary steam turbines which are aggravated by the use of higher steam pressures.

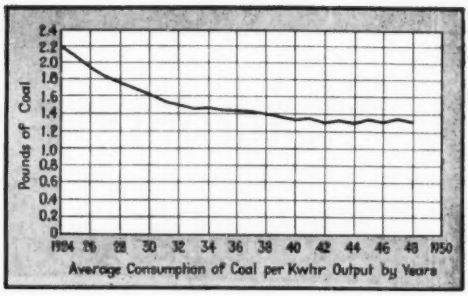
Reliability of power supply for the motor-driven auxiliaries was sought by the use of separate house turbines, and at the beginning of this period house generators driven from the main turbine shaft were introduced. Full voltage for across-the-line starting for squirrel cage motors was beginning to be used for simplicity and economy. Variable speed motors were generally used for induced and forced draft fan drives. Dual drives with both a motor and a steam turbine connected to the same shaft were used in a few plants for essential auxiliaries for reliability and for heat balancing.

Steam Reheated

Steam pressures jumped from 400 psi to 1,200 psi in a relatively brief period, and, since the maximum steam temperature was still limited to 750 F, this led to the consideration of reheating. For base load plants

Prepared by GEORGE C. DANIELS, *Chief Mechanical Engineer, The Commonwealth & Southern Corp*





IN quarter century pressures have risen from 400 to 2,300 psi and total steam temperature from 700 F to 1,050 F. Coal per kwhr has been reduced more than 40% in 25 yr. Average coal consumption per kwhr has hovered near 1.3 lb for nearly nine years

this appeared to be economical although the added complications and the possible increased operating difficulties were at first viewed with some concern. In the first reheat installations the reheating took place in separately fired boilers. Limitation of condensing water supply in some locations had placed a premium on the steam cycle with the lowest heat rejection to the condenser.

The use of higher steam pressures focused attention on better controls for feedwater, steam pressure, and steam temperature and also on obtaining cleaner steam from the boilers and the elimination of oxygen from the feedwater.

The binary vapor cycle has been slowly developed during the past quarter century. The first mercury turbine was installed in 1923 as an experimental unit, and its successful operation has been followed by a few other installations which have been very satisfactory, but the overall economy of the binary cycle has always remained somewhat in doubt.

Steam Generators

In 1925 the word "steam generator" for a boiler with its superheater and heat reclaiming equipment was coined. The term "boiler horsepower" soon became inadequate to describe the size or output of a boiler, since application of water walls on existing boilers allowed double the former ratings to be carried with only a slight increase in boiler surface, and in new designs of boilers the term became almost meaningless. Several terms to express boiler output were proposed and used to a limited extent, but in the course of a few years the established method of expressing boiler capacity came to be in pounds of steam per hour. Publication of Keenan's steam tables up to 1,200 psi in 1925 made a more accurate analysis of steam cycles possible.

Methods of ash handling, always a considerable item of expense and trouble, were undergoing a change and were a factor leading to the development of slag-tap furnaces. Hydraulic handling of ashes received considerable attention, and in 1926 four utility companies reported that the cost of handling ashes by sluicing averaged 34¢ per ton compared with an average of 44¢ per ton handled by industrial cars in the conventional way. Hydraulic handling of ashes has become almost standard practice today.

Condensers

Condensers previous to this era consisted of a shell containing as many tubes as possible. Developments in design of condensers which increased the heat transfer led to the use of so-called short surface condensers, but soon it was discovered that the tube surface in the old condensers could be materially reduced by laning, thereby increasing the heat transfer and the vacuum and reducing the refrigeration of the condensate. Single-pass condensers and divided water boxes began to be used. Special attention was paid to getting the steam into the hot well and to the deaeration of the condensate. Condenser leakage constituted a major problem with the high heat input into the boiler surfaces and at the higher pressures which made it necessary to keep the feedwater at the highest purity. This led to the development of rolled tube joints at both ends of the condenser to replace former packed joints.

Pulverized fuel firing began with a separate pulverizing plant commonly called the bin and feeder system, but soon direct-fired installations with turbulent-type burners appeared and these made smaller furnaces possible. It was soon discovered that a high heat release per cubic foot of furnace volume increased slagging difficulties, and the design of furnaces has become continually more conservative. This trend has been augmented by the use of the poorer grades of coal.

Generator Ventilation

The closed system of generator ventilation developed early in this quarter century period did more to decrease the outage hours in connection with the generator than any other development in the previous ten years. Hydrogen cooling of generators had been given considerable thought, and some generators built in 1926 were designed suitable for the later use of hydrogen if desired. An experimental use of hydrogen in a small generator was tried in 1926 but it was not until some years later when large 3,600 rpm turbines began to be built that hydrogen cooling of generators could be justified economically. Turbines of 3,600 rpm, as large as 10,000 kw noncondensing, were built by 1926 and were used as superimposed turbines or on a reheat cycle, of which a number were designed to operate at a pressure of approximately 550 psi.

Superheaters and Economizers

Radiant type superheaters, after passing through several years of development, were being used in combination with convection superheaters, but the interdeck superheater in horizontal tube boilers was still used extensively. Pressure drop through the superheaters was usually kept low due to the comparatively low initial pressure. This resulted in overheating and loss of elements due to improper steam distribution, especially during low loads. Superheater supports were hard to maintain and keep in service. The increased use of bent-tube boilers with the pendant type of superheater and single instead of multiple elements with higher pressure drop, cured many of the difficulties formerly encountered.

Steaming economizers were introduced to avoid the temperature limitations encountered in conventional designs due to higher temperatures of the feedwater.

Caustic Embrittlement

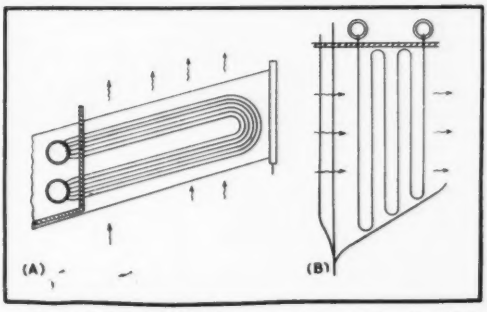
Caustic embrittlement of the boiler steel was the cause of much concern and discussion, especially at the higher pressures. Riveted drums for 4-in. tubes of fairly conventional design could be built for pressures of 600 psi and bent tube boilers with 3½-inch tubes for pressures of 450 psi. In excess of 700 psi forged boiler drums were required, and somewhat later hammer-welded drums came into use which removed the danger of caustic concentration in the riveted seams. Boiler feedwater treatment was the subject of much discussion and experimentation and was blamed for many tube failures that subsequent investigation found were due to other causes.

Temperatures Start Rising

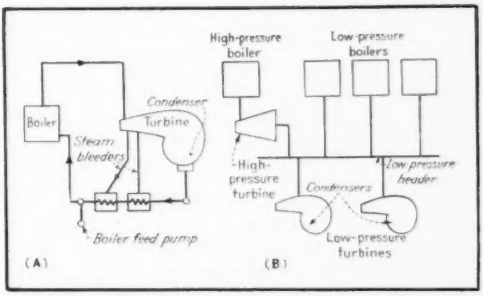
With the rising steam pressures it had long been recognized that an increase in steam temperature above 750 F would increase economy and result in a reduction in investment if no marked changes had to be made in the steam generator. It would also result in a reduction in turbine maintenance due to the lowering of the moisture content in the lower stages. The solution to obtain higher steam temperatures lay in reducing the temperature difference between metal and steam and the temperature stresses in the tubes. To accomplish this it was proposed to decrease the average heat transfer rate, use higher steam velocities, smaller tubes, parallel flow, eliminate laning of the gases, and prevent secondary combustion. By these methods it was thought possible, with the steels available, to go to a steam temperature of 800 F. However, it took several years before the temperature limit of 750 F was revised upward. Most designers of this time still regard 400 psi, 750 F, as the highest practical pressure without reheat due to the moisture in the turbine exhaust.

Tests of various steel alloys for higher temperatures and long-time tensile tests at elevated temperatures were begun and gradually permitted the substitution of an accurate method of design instead of the use of approximate safety factors.

A general reduction in investment per kilowatt of capacity resulted from the advances in fuel burning



TWO REPRESENTATIVE forms of superheater—(A) Multiple loop (interdeck) type—(B) continuous loop (pendant) type



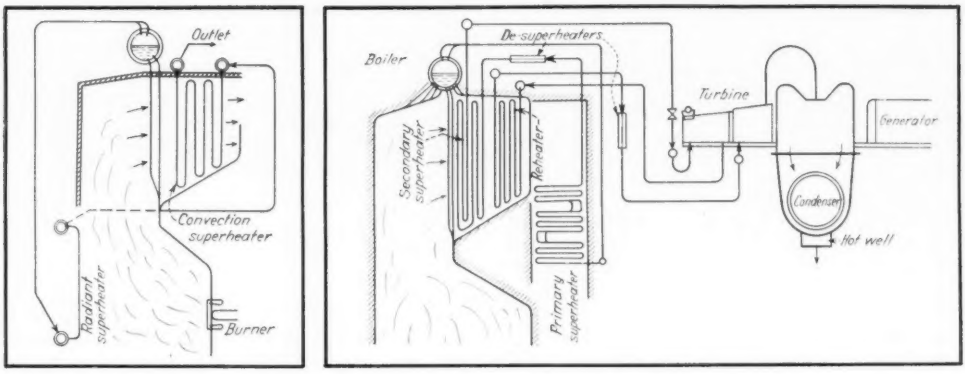
REGENERATIVE EXTRACTION and superposition principles—(A) Simple regeneration showing two bleed heaters—(B) high-pressure turbine exhausts into low-pressure turbine header

equipment, permitting burning of greatly increased amounts of coal, so that the boiler size was no longer limited. The use of water walls also removed the limitation on size due to refractories. The increase in boiler capacity simplified design of the boiler plant, permitting a single row of boilers parallel to the turbine room, which resulted in more light, accessibility, and a reduction in floor space and cost. It was recognized that the rate of boiler output or the kind of fuel used was not as important in obtaining high availability as were details in design, construction, and operating skill. Early in this period some thought was given to the possibility of using only one boiler per turbine due to the increasing reliability of boilers and their equipment. However, this was not attempted until several years later.

In 1930 outdoor boiler installations were being advocated by some engineers. Over the ensuing years numerous installations of this design were made, and more recently outdoor turbine installations were made. The high building costs of recent years have focused attention on this type of construction.

Boiler Ratings Grow

The first 1,000,000-pound-per-hour steam generator was put into service in 1929. This unit consisted of two boilers set over a single furnace. Two years elapsed before a boiler designed as a single boiler and furnace of this size was built. Meanwhile the turbine sizes



COMBINATION radiant and convection superheater (left) and typical resuperheating cycle (right)

grew even faster than the boiler sizes to supply them. In 1929 an experimental turbine of 10,000 kw capacity for 1,000 F steam temperature was installed, but the upper temperature was approached cautiously during a long period of experimentation by means of a separately fired superheater.

With increased boiler sizes automatic combustion controls were more fully developed which some years ago were thought to be as good as good manual control, whereas at the present time they are considered almost indispensable for good operation and reliability.

Welded Drums

Proposed specifications for fusion welding of boiler drums by the American Society of Mechanical Engineers in 1930 were not adopted by the Boiler Code until 1932. This resulted in lower boiler construction costs for the higher pressures and larger diameter drums for the installation of numerous devices for attaining dry steam, thereby reducing the turbine blade deposits that were becoming very troublesome.

By 1931 steam temperature of 825 F was in use and the size of the 3,600 rpm turbo-generators had increased to 15,000 kw condensing and 18,000 kw noncondensing. Operating records of the later design of boilers indicated an availability factor as high as that of the turbines, and in 1935 the first installation was made with only one large boiler supplying a high pressure turbine.

For several years during the depression, little, if any, additional generating capacity was installed, but research continued on the property of metals at higher temperatures and within a few years boilers and turbines were available for operating with 900 F steam temperature.

Superposition

By the middle of 1935 loads and outputs again increased with the result of much activity in superposition of 900 psi and 1,350 psi, 900 F temperature units on plants of 200 psi pressures and which were not over 20 years old. Superposition permitted generating capacity to be added in relatively small increments in line with the broad growth and resulted in modernizing old plants if existing facilities for fuel and condensing water were adequate. Superposition was particularly attractive for metropolitan areas for which new sites and new facilities were expensive and where the existing site was wholly utilized. It also permitted an increase in capacity where the supply of condensing water was limited. An added advantage occurred in cases where the installed turbo-generator capacity was in excess of the steam capacity, since the excess turbine capacity was available for superposition without rendering inactive low pressure boiler equipment.

One Boiler, One Turbine

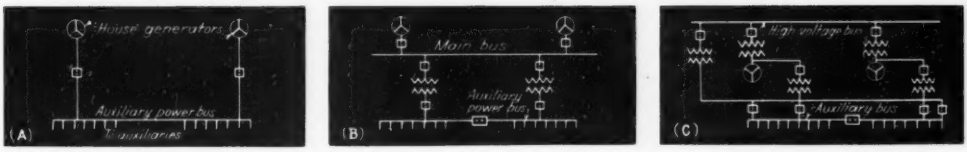
The high degree of operating reliability of the newer steam generating equipment made feasible the adoption of the unit principle of one boiler per turbo-generator unit with appreciable savings in unit investment, and most of the superimposed installations were made on this basis, which contributed materially to their justification.

While superposition in many cases resulted in a higher cost per kilowatt for the additional capacity than for a high pressure condensing installation of a capacity corresponding to the combined capacity of the low pressure and superimposed high pressure units, yet the total expenditure was less and the added capacity fitted into load growth to better advantage and postponed the larger installation until complete superposition had been accomplished.

Turning Gears, Chlorination

Higher steam temperatures increased the required time to put turbines on the line, especially after a short shutdown, due to the possible distortion of the turbine spindle. This difficulty was materially decreased by the use of turning gears which rotate the spindle slowly during the time the turbine is idle.

Chlorination of circulating water began to be practiced and within a few years was considered essential for economy of operation even though most condensers were being built with divided water boxes for ease of cleaning and repairs while operating.



TYPICAL auxiliary power supply—(A) from house generators—(B) from main bus—(C) off generator leads with transmission backup

Creep Tests

Creep tests started in 1931 had by 1936 given sufficient information on alloyed steels to enable the turbine manufacturers to build turbines for 1,000 F, but it was some time before superheaters could be obtained that could reliably produce this temperature although 900 F steam temperatures were adopted without much risk of excessive maintenance. The need of revised steam tables for temperatures above 825 F became evident from the findings of the Third International Steam Table Conference in 1935 and revised steam tables were published in 1936.

3,600 Rpm Units

The size of 3,600 rpm condensing turbines that could be built steadily increased as suitable metal and methods of fabrication were developed. The use of the 3,600-rpm turbines resulted in reduced cost and space requirements. Their use in the larger sizes made the use of hydrogen cooling economical on account of the great reduction in generator losses at the high speed, and the use of hydrogen also made it possible to build generators of higher ratings than with air cooling. By 1938 the use of 3,600-rpm turbines with hydrogen cooling had become standard practice, and the majority of turbines ordered during this period were this type.

Welding advances brought extraordinary economic and technical changes in design, construction, and maintenance of equipment, which resulted in decreased outage for boiler units. Welded steel condenser shells were being welded to turbine steel exhaust openings and eliminated a source of air leakage into the condenser.

In 1939 considerable though was given to forced circulation boilers as used in European practice, but it was generally felt that the natural circulation boiler and water walls would be fully explored in this country before there would be any appreciable swing toward forced circulation boilers.

Tangent Water Walls

The straight tube type of boiler for high pressure service had almost disappeared from new installations by 1940. Tangent tube-to-tube water walls had largely replaced the blocks and fin tube construction. Elimination of intermediate headers in furnaces by the use of extra long continuous tubes was made possible by field welding. Welded stub type headers for high pressure superheaters and economizers, with the elimination of headers with handholes and rolled tube joints, removed one of the most frequent and troublesome causes of boiler outages.

During the war years when utility plant expansion was curtailed and the power demand increased, the effects of previous years of endeavor to improve reliability of operation were shown by the all-time high of utility operation of 93.86% of maximum possible unit operation during 1941. The extended time between overhauls and high load factors during the war resulted in no serious difficulties or excessive maintenance.

During the war years an attempt was made to establish standard rated sizes and bleed pressures for 3,600-rpm turbines for several steam pressures and temperatures in the larger capacity range. While the industry was slow in adopting these preferred standards, the trend has been toward their use to obtain quicker delivery and to lower the cost.

Reheat Reappears

Much generating equipment was installed under programs developed before the war for pressures of 900 psi or 1,200 psi, with temperatures of 900 degrees. By 1946 temperatures of 1,000 F to 1,050 F were adopted by several companies for their new stations, and 3,600-rpm turbines in sizes up to 100,000 kw were being built. With the increased cost of coal reheating again appears to be economical with the higher steam temperatures, and many new plants or additions are being built with reheating temperatures up to 1,000 F. The problem of reheating has been greatly simplified by the use of a single boiler per turbine on the unit basis of operation which has become standard practice. Larger furnace volumes, wider superheater tube spacing with parallel flow of gas and steam, higher pressure drops, and better tube material should result in a high degree of boiler availability at these temperatures.

The community drives to abate the smoke and dust nuisance have resulted in much attention to fly ash collectors of high efficiency and were also responsible in no small measure for the development of the cyclone furnace design which collects most of the ash, in the coal, in the form of molten slag. The gradual increase in ash content of the coal since 1941 has also augmented the problem.

The increased difficulty of inspecting and cleaning the inside of long and bent boiler tubes, many of which terminate in headers or small drums, gave rise to the acid cleaning method which has become accepted practice, with a great saving in boiler outage time and cleaning expense.

During the past few years the gas turbine has received renewed attention, and, as larger sizes are developed and the efficiency increased, they will undoubtedly become competitive with the steam cycle wherever economical sources of oil or gas are available.

Fuel Utilization and Steam Generation

Advent of suspended boilers, vertical tube-banks, pulverized fuel, superior metals, superheat, water-walls, soot blowing, wet bottom furnace, air pre-heater, ash collection, acid washing and cyclone furnace each related to needs of prior period

TWENTY-FIVE YEARS AGO the art of steam generation, particularly in the public utility industry, was just ready to undergo its greatest period of development.

Early boilers were generally built in small units and the steam produced by several was combined to drive one turbogenerator. The brick furnace settings required high maintenance due to the unequal expansion resulting in cracks and air leakage. Larger boilers not only amplified these difficulties, but in addition, due to the increased height of walls, imposed higher crushing loads on the bricks themselves, already in difficulty due to high temperature. Wall failures were common. Outage and maintenance costs were high.

Slag accumulations on the walls of brick set boilers also washed the surface off the refractories. Rebuilding was frequent and expensive and required long outages.

Hung Walls Appear

The limitation in wall height which was imposed by the physical characteristics of brick resulted in hung walls coming into use. In this type of construction, the brick weight is carried by special shaped refractory, hung on structural members and now used either alone or in combination with water cooled walls.

Gradually, designers began to install water cooling in the walls. At first it was water-cooled supports for brick walls or a few water tubes in the brick work, finally resulting in the development of the water-tube wall now so generally used on all types of furnaces. With this construction it became possible to cover as much of the furnace walls with heat absorbing surfaces as is desired.

Originally tubes were installed in such lengths as could be shipped on freight cars or otherwise handled. However, with the advent of better welding techniques, tube lengths are now welded in the furnace without limitation by any other consideration than circulation.

Vertical Tube Banks

The power plant boiler of twenty-five years ago was generally arranged with 15-deg inclined tubes and cross or longitudinal drums, with or without superheat. Some of the larger boilers were beginning to take the Stirling form of V or W type with upper and lower drums.

Development of adequate steam separating devices in steam drums of modern high-capacity, high-pressure units has permitted the more general use of substantially vertical tube banks, advantageous from the standpoint of higher circulation and greater resistance to slag adhesion. With the higher rate of circulation, steam bubbles are scrubbed from the tube surfaces. Sluggish steam bubbles tend to alternately wet and dry a surface, the evaporation laying down a deposit of solids from the water which will reduce heat transfer, and finally result in blisters and tube loss.

Furnace configuration has changed from a small low-head fire box through the higher settings of stoker practice until it has reached the present day substantially rectangular shape with vertically long flame travel in which combustion and gas temperature reduction can take place. The furnace can be followed by either an open pass before the superheater and economizer or gas can go directly to the superheater without any convection surface other than the necessary screen tubes between the furnace and the superheater. Sometimes boiler convection surface is placed between the superheater and the economizer.

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Furnace Proportions

The size and shape of the furnace and the disposition of the heat absorbing surfaces must follow established principles to result in a satisfactory temperature of the gas entering the convection surface of the boiler, screen tubes or superheater.

In order to provide more surface in high-pressure high-capacity boilers without increasing furnace volume, designers may resort to twin furnaces. Each furnace can be separately fired and controlled, permitting greater flexibility of boiler operation.

The change in firing from stoker to pulverized fuel was a necessary and logical development.

Stokers reached the limitation of physical size, at a point where the stoker area and depth of coal it was possible to impose on that area were still not enough to meet the steam demand of the boiler.

Pulverized Fuel Firing

Burning fuel in suspension allows operators a greater range of coal and also enables them to use the cheaper grades of slack coal, washery refuse and by-products of dry cleaning, previously of no value on either grates or stokers.

Bin and feeder systems pulverize coal at a substantially uniform rate, irrespective of boiler load and store the pulverized coal at the boiler. Unit systems pulverize coal as required by boiler rating.

The problem of transporting coal through piping when much surface moisture was present made coal drying necessary in such degree as to overcome the difficulty. Wet, raw coal would not flow through grid and steam table dryers easily, and heat and operating power made them expensive. Thus the practice of mill drying, whereby heated air or gas was taken into the mill, to absorb some part of the surface moisture during pulverization, came into use and is employed generally today.

The disposal of this drying air or gas with its entrained dust and the disposal of coal dust bearing transport air, together with pumping, storage and other features of the bin and feeder system led some designers to favor unit pulverizers. Coal in the course of pulverization in the mill is dried by the hot air, which is in itself the transport medium and is fed directly into the furnace as part of the air of combustion, thus saving the drying heat and disposing of the entrained dust advantageously.

Metallurgical Advances

Progress of power plant practice has created an incessant demand for new and better materials of construction to allow the designer to employ higher temperatures and pressures. Thus the advance in metallurgy has pushed the safe operating pressures and temperatures to their present state and made such operation economical.

The development of the turbine and condenser, however, allowed the operators to gain the savings of higher steam temperature. The turbine, requiring no internal lubrication and capable of utilizing these higher steam temperatures at higher efficiency, opened the way for the further development of superheat practice.

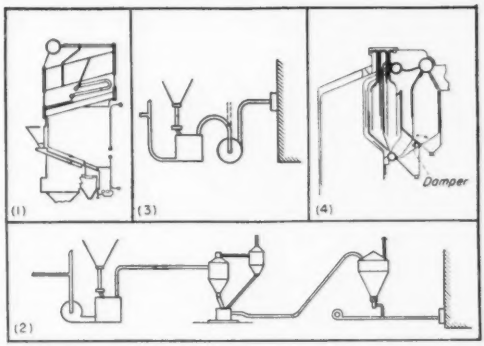

FIG 1—SINGLE-DRUM, inclined-tube boiler with interdeck superheater, stoker fired
FIG 2—TYPICAL bin and feeder pulverizing system
FIG 3—UNIT MILL type pulverizing system
FIG 4—BOILER with damper control for steam temperature

The practice of superheating steam and passing it through some part of the turbine cycle, and then returning this steam once again to the boiler for reheat became common and was used then as it is today to overcome a limit in steam temperature imposed by existing materials.

The needed control of steam temperature has been met in many ways, all successful either alone or in combination. Each method uses a sensitive element in the steam line at the superheater outlet to control the operation of the equipment which maintains temperature.

By-pass dampers, in the vicinity of the superheater, are very commonly used as a control. Where employed, the opening and closing of the dampers is accomplished by an actuator, controlled by the sensitive elements. The opening of the damper allows the boiler gas to by-pass some portion of the superheater surface and thus drop the steam temperature. Conversely, closing the damper brings more of the superheater surface into use and raises the steam temperature.

Superheat Control

Attemperators employ the desuperheating principle. In the spray type attemperator, the sensitive element controls the opening and closing of spray water valves through which feed water is mixed with steam, generally between the primary and secondary sections of the superheater thus allowing all water globules to be evaporated before leaving the superheater. In the submerged type a proportion of the steam is diverted from the primary section to desuperheating coils immersed in circulating boiler water, some of which is evaporated by heat given up by the desuperheating steam before its admission to the secondary section. In this section enough heat is added to maintain correct temperature at the sensitive element.

Another method of control employs indirect condensing surface in the superheater inlet header. Saturated steam is passed over this surface through which

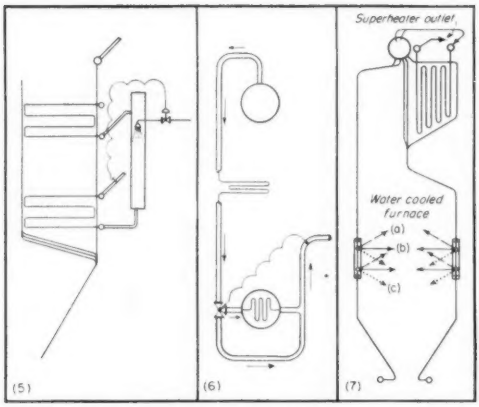

FIG 5—SPRAY TYPE ATTEMPERATOR for steam temperature control

FIG 6—SUBMERGED FORM of attemperator

FIG 7—SUPERHEAT CONTROL by means of tilting burners —(a) up for maximum superheat, (b) horizontal for average and (c) down for minimum

part of the feed water is circulated. The steam, with the condensation thus formed and still at saturation temperature, is passed to the superheater where the condensation is re-evaporated. Valves actuated by the sensitive element control the flow of feed water.

In the furnace, steam temperature may be controlled by changing the angle of some of the burners. Certain types of burners are made movable in the vertical direction and it is possible, by their adjustment, to raise or lower the zone of active combustion in the furnace by which the amount of heat absorbed by the water wall surface is varied with the position of the flame, and the temperature of the gas entering the superheater is raised when the zone of active combustion is raised or lowered when the zone is lowered. The increase or decrease in gas temperature will raise or lower the steam temperature.

When arranged in conjunction with another type of control the total range may be increased. Thus, used in conjunction with dampers in a dry bottom furnace, the burners are arranged to tilt to their maximum position, after which the dampers operate to extend the control range. In a wet bottom furnace, generally the dampers operate first and the burner tilt becomes supplementary. Another common form of control for steam temperature in dry bottom boilers is the tilting burner in conjunction with a desuperheater. In either combination the damper or desuperheater is used to extend the control range by bringing the temperature conditions within the limits of the burner tilting range.

Heat Distribution

The temperature of gas entering the superheater, and in turn the steam temperature, is also controlled by varying the amounts of coal burned in upper and lower banks of burners and to some extent by changing the air supply to increase the length of flame.

Where divided furnaces are installed, one furnace can be used to generate steam and the other furnace used for superheating surface, each furnace being fired separately to maintain steam demand and steam temperature.

Slag accumulation on the walls and transfer surfaces of the boiler has always been a problem, whether walls are of refractory or water cooled tubes, by blanketing the surfaces so that heat absorption is retarded. In the furnace the blanketing causes steam capacity to fall off, resulting in higher gas temperature to the superheater and a rise in steam temperature. If the gas temperature becomes higher than the temperature at which the ash in the fuel softens, this slag then plasters the superheater, blanketing the superheater surface and plugging the spaces between the tubes. Exit gas temperature then rises and the draft loss through the boiler increases, both of which are definite losses.

When blanketing was local, increased mass flow through remaining openings often caused damage due to torch action.

Water Cooled Walls

Water-cooled walls where an advance in the art of steam generation because with these walls it was possible to spray the accumulated slag with either steam, air or water or an air and water mixture to remove the slag and maintain steam output and temperature without too much damage to the walls. Also, by dropping the rating, it is possible to cause slag to crack and shed off the walls due to changes in wall temperature.

To recover the heat lost with the exit gas and to reduce the draft loss caused by slag in the convection surfaces of boiler superheater and economizer, it was necessary to lance the boiler through a multiplicity of doors. This was hard laborious work and as boilers grew in size became almost impossible in some locations. Because deslagging was a slow process it became practically continuous, utilized great quantities of steam or air and required extra attendants and much clear space around the boilers in which to manipulate the lances. Air infiltration was high due to the continuously open lance doors. Soot blowers were developed to improve the boiler cleaning.

Soot Blowing

The first soot blowers were fixed in their position in the boiler and consisted of a tube along which nozzles were spaced. Steam was admitted to the tube and it was revolved in its supports by hand or a chain wheel. In the cooler zones these were generally satisfactory, but in the zone of elevated gas temperatures maintenance was excessive. Thus the retractible blower, which could be withdrawn from the boiler, was developed. Telescopic blowers were developed for use where clearances outside the boiler were limited. Both these blowers, because they contained generally two nozzles in the end, had far greater range and cleaning power.

On large boilers, where the lancing of side water walls was so costly and laborious, it was a natural step to remove slag with a wall deslagger, developed on the retractible principle so that it could be withdrawn from the furnace for protection.

The labor of hand operation of numerous soot blowers on large boiler installation consumes considerable time and the economy of controlling blowers by push button or automatic sequence control from a control panel was evident. Saving in the amount of the blowing medium could also be made due to the operation on a timed cycle.

Wet Bottom Furnace

With the advent of pulverized coal and the permissive use of a wider range of fuels, some with very low fusion temperatures became highly economical. The demand that boilers burn not only these low fusion coals but those of higher fusion as well, led to the adoption of the wet bottom furnace. With this design, incandescent slag is allowed to run down the walls and accumulate on the furnace bottom from whence it is tapped off either continuously or at intervals.

The waterwall contributed an integral part to this design due to its ability to withstand the flow of molten slag which would ruin refractory walls in a short time. In wet bottom furnaces, about half the ash falls to the bottom and its residual carbon is usually burned out completely, thus not only reducing stack dust emission but also combustible loss. Ash in the form of slag is easier to catch and handle than fly ash, and the wet bottom furnace, therefore, contributed to general plant betterment by its ability to capture more of the ash.

In the first designs of pulverized fuel furnace with refractory walls the heat release per cubic foot of furnace volume was kept low because of the limits imposed by the brick, which eroded under the high temperature and action of the slag.

Heat Release Rate

As water cooled walls came into more general use, designers took advantage of the steam generating surface thus afforded and arranged the surface in more compact units, to reduce overall costs, expecting to get high heat absorption from high gas velocity. The smaller furnaces and more compact surfaces, however, resulted in high gas temperature and high gas velocity which caused the slag to blanket the absorbing surfaces and lower the efficiency, more aggravated as the quality of coal became worse.

The present practice is to have larger furnaces with relatively low heat release, and to provide large wall area and widely spaced convection and superheater surface to keep gas temperature low enough to prevent slag accumulations and with open spacing of tubes to prevent bridging and improve cleaning access.

Cyclone Furnace

A new approach to the problem of improved combustion in the furnace and reduction of ash and slag leaving the furnace with the combustion gases is the cyclone furnace.

In principle it employs a slightly tilted circular furnace or firing tube, external to and discharging into the secondary furnace. The coal is burned in the cyclone burner in a highly turbulent state at a temperature above the fluid temperature of the ash.

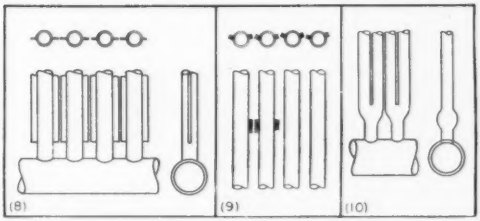

FIG 8—FIN-TUBE water wall
FIG 9—STUD-TUBE water wall (partially studded)
FIG 10—TANGENT BIFURCATED tube wall

Crushed coal and air are admitted tangentially at high velocities, whirling the coal-air mixture during the combustion period. Coal particles are trapped in a layer of molten ash on the inside of the cyclone furnace are burned at high combustion rates by the scrubbing action of the hot secondary air. Approximately 85% of the ash is centrifuged out as molten slag which is run off to the slag pit. The cyclone furnace delivers gas to the secondary furnace and heat absorbing surfaces substantially clean, with a minimum of ash and slag. This simplifies the de-slagging and soot blowing problems and reduces the entrained ash content of gases going to the gas cleaning equipment, making it easier to meet stack emission limits.

Air Preheaters

Air heaters came into use because they raised plant economy. With economizers as the last piece of heat recovery equipment receiving heat from the flue gas, and with feed water heaters of various kinds in the water circuit, the outlet gas temperature in the economizer was limited by the inlet water temperature to the economizer.

With air heaters in the flue gas circuit, heat may be extracted from the gas down to the economic limit which is generally conceded as the temperature where condensation will take place with the resultant corrosion and pugging. The original heaters were either of the tube or plate type, with the regenerative heater as a later development.

The combustion air temperature was thus raised as high as could be justified, however, maintenance on stokers increased with too high air temperature. This set the limit on air heating practice of the stoker era, but with the advent of pulverized coal, air temperatures were increased, because not only could the economy of lower exit gas temperatures be effected but the high air temperature improved the drying of coal for pulverization.

Smoke Emission

With the hand fired boilers and later with stokers, cinders and smoke had always been troublesome, cinders because of the nuisance to the immediate vicinity and smoke as a contributor to atmospheric pollution. They also represented an inefficient condition and loss in the boiler. Cinder discharge was reduced by numerous types of collectors which did a mediocre job and

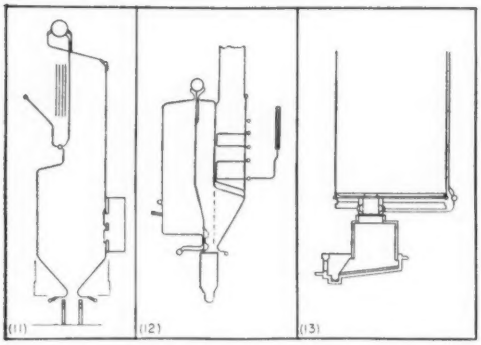

FIG 11—OUTLINE OF BOILER with dry bottom furnace
FIG 12—WET BOTTOM furnace, dry open pass, spray-type attemperator
FIG 13—BOILER OUTLINE showing wet bottom furnace

which satisfied the condition of the times, if the boiler was not forced beyond reasonable steam output.

As a step toward better emission, boiler setting heights and larger combustion space resulted. However, with the wider use of pulverized coal, the then existing means of nuisance reduction were found inadequate. Pulverized fuel produced no emission that could be called smoke because of the completeness with which coal was burned, but in dry bottom furnaces as much as 85% of the ash was discharged from the stack as dust, most of which was so fine that it passed through the existing collectors without much diminution.

Ash Collection

The original ash collectors were either centrifugal or washers. Centrifugal devices were good up to a limited efficiency and washers were subject to high maintenance and in cold weather precipitated water locally, so that gradually a trend was toward electrostatic precipitators as the best means of stack improvement.

Mechanical and electrical ash collectors in many cases are now used in series to reduce discharged ash to a minimum. Visual emission is far less and there are no large particles to drop close to the plant.

Inclusion in the steam generating installation of superheater, economizer, air heater and dust elimination equipment and the increase in gas velocity through these accessories has raised the pressure of draft producing equipment far above previous requirements. To this end, new designs of more efficient fans, capable of large volume of high pressure have developed. In addition, the erosion of dust on induced draft fans has led to improvements in erosion-resistant wheels and wear plates.

Thought is now turning toward the elimination of the induced draft fan by using a doublecased boiler and high forced draft pressure between the two casings. This would avoid the maintenance problems of the induced-draft fan.

Development of fluid and magnetic couplings, wherein the slip between the driver and driven halves of the coupling is utilized to vary the speed of fans, pumps and other equipment allows the designer to use the most economical constant speed motor and attain the variable delivery of the equipment by varying speed.

The wound rotor motor, and the liquid rheostat, whereby variable motor speeds may be attained also gives control of output by varying the speed.

In the case of induced draft fans, additional savings in maintenance can be attained from the reduced abrasion of the ash when less fan delivery, and therefore, lower speed is required during low boiler load periods.

Water, Steam Purification

The older type low pressure boilers were not too sensitive to water conditions. While the better the water the better the performance was still true, simple types of water treatment were all that was necessary. The high pressure, high capacity boilers in use today cannot stand any form of solids tending toward formation of hard scale and therefore must be operated solely on condensate or softened make-up. To accomplish this, water treatment plants have come into usage, externally pre-heating the raw water so that substantially all hardness is removed, in addition to the phosphate and caustic treatment as required to keep proper water conditions in the drum. To maintain the low solid concentrations required by the high pressure boilers continuous and intermittent blow down facilities are provided. Flash tanks, to recover the heat and water as lower pressure steam are often installed, and the plant chemist makes frequent periodic checks on the boiler water to see that conditions of pH and concentration are kept within limits.

Steam purification has also reached new standards of perfection, not required by equipment of twenty-five years ago. At that time, with low pressure steam, two, three or even five percent of moisture carry over from the drum was normal, and no particular attention was paid to entrained solids in this moisture.

Turbine Fouling

Turbines can be ruined by a slug of solid water carried over from the boiler, which can cause the turbine to tear itself apart by the water impact. Also with the heavy metal walls and close clearances employed, the differential contractions and stresses set up by the relatively cold water can cause misalignment and cracks. In addition, whether entrained in the moisture or as a gas, silica is carried over to the turbine where it precipitates out on the surfaces in the low pressure end, and reduces the capacity output to a point where economy demands that it be washed off. While this is usually accomplished by running the turbine slowly at a time when being fed with a mixture of hot water and steam, it is another problem of plant operation.

These conditions in the boiler are now the subject of further consideration by the water chemists who contemplate the removal of silica by additional pre-boiler treatment at the same time as the hardness is removed.

The increase in the number of plant auxiliaries and the steady climb in operating temperature and pres-

sure has resulted in more constant and higher technical attention. The consequences of human failure or inattention are increasingly serious, as a few seconds of inattention may result in the loss or outage of millions of dollars worth of equipment. In addition the desire to keep operating costs as low as possible, to increase safety and improve the continuity of service have resulted in the development of control and supervisory equipment to a degree never required by the older type of equipment.

Automatic combustion control has been developed, so arranged as to regulate the amount of coal fed to the units and to vary the delivery and pressure of forced draft fans and furnace draft in response to the rise or fall in the pressure of the steam at the boiler outlet. The functions of the control system are made either automatic or manual at the discretion of the operator at the control point enabling him to operate the system as an automatic unit or to manually control any piece of equipment remotely, or to designate the control of any equipment to other operators stationed locally at the equipment.

Feed Water Control

Feed water control has been refined to meet the more severe conditions of present operation. Coordinating the steam flow of the boiler with the water flow required and adjusting these to maintain drum level relieves the operator of this as a physical duty, by either increasing or decreasing the speed of boiler feed pumps where the type of drive permits or by opening or closing a control valve in the feed line where constant pump speed is maintained. As with combustion control the operator can choose between automatic or manual control as conditions require.

To see the water level in the glass has become a major problem. As setting height increased the gage glass got further from the operator's vision. Remote level indicators, through a combination of electrical and mechanical motions bring the water level image to the operator, but are subject to electrical or mechanical failure. Television has also supplied an answer. Usually two types of remote indication are installed for safety in case of the failure of either.

Instrumentation

Instruments generally give to the plant personnel the knowledge necessary to operate the boiler plant safely and economically. Indicating and recording instruments show the operator conditions throughout the plant as well as maintain a record for comparison or improvement of these conditions. Their omission would multiply the number of attendants in the plant.

Alarms and supervisory instruments are now employed for every conceivable purpose throughout the plant, used either alone or in conjunction with each other. They are used to warn operators of such plant variations as loss of coal feed to mills, high bearing temperatures, high or low water in the drum, failure of equipment or electrical circuits, smoke emission or, when used in conjunction with other supervisory instruments, can shut down equipment before serious failure results.

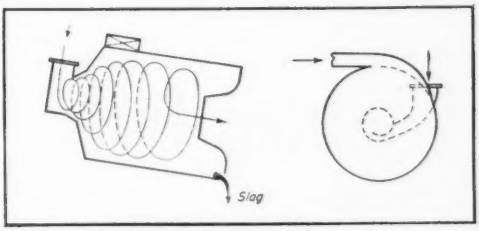

FIG 14—PRINCIPLE of the external combustor, known as the cyclone furnace

Acid Washing

The complexity of shapes to which modern boiler tubes are bent has made the acid washing of boilers almost mandatory. Once it was the practice to internally clean the tubes by turbine or vibrator driven tools to remove the scale and keep tubes in condition to transfer heat easily.

Higher operating pressures made cleaner tubes absolutely necessary as the slightest scale resulted in loss of tubes very quickly. The practice of cleaning by boiling with acid and rinsing with a solution to inhibit further acid action has actually lessened internal cleaning and labor costs. Turbining is now resorted to only under extraordinary circumstances. Acid washing also cleans drums and headers, which was a separate operation when tube cleaners were used.

Welding Benefits

Field welding has cut the leakage of ducts and gas flues to a minimum, and the application of insulating blankets and block material on wire splines has cut the labor and time of installation greatly.

Improvement in the shop and field welding technique, and in automatic welding machines in the shop have contributed to the fabrication of plates and tubes and the x-ray has made it possible to internally inspect the material and workmanship of both the parent metal and the weld. This advance has made the fabrication of drums of the required thickness and tubes of the required length possible without which the development of large capacity, high pressure, high temperature boilers would not have been possible.

Imminent Prospects

Once again the power industry stands at the beginning of an era of development. The lines are not too clearly drawn as yet but are beginning to take shape. Existing practices will be further improved in the future as they have been in the past. The gas turbine, using the gaseous products of combustion from a combustor to drive the generator, has been developed to a point of operation with pulverized coal as the fuel. Improvements and operating installations can be expected. Boilers, using atomic energy as the source of heat are in the discussion stage, and while the problems of material handling, control, safety, disposal of waste and many others are yet to be solved, the recognition that they exist will lead to the solution.

Steam Turbines and Condensers

Evolution of increased ratings, multiple extraction, resuperheat, high temperature metals, standardization, antidotes for turbine deposits, turning-gear, gas turbine, improved condenser performance, deaeration and welded shells

STEAM TURBINE design and construction in the last twenty-five years has been predominately influenced by the desire to increase the reliability of operation and to decrease the fuel consumption and capital investment per unit of output. Since many turbines consume their purchase price in fuel in less than a year, the decrease in operating costs resulting in improved efficiency has always been of much greater significance than the reduction of first cost of the turbine alone. Much emphasis therefore has been put on improving the economy by the use of new knowledge, new materials and new tools and manufacturing technique.

In 1924 the first 600 psi turbines were placed in service and in 1925 the first turbine for 1,000 psi. The latter turbine which was operated a year later at 1200 lb was designed for a pressure twice as high as any previously used and for three times the pressure of only two years before. Many new design problems were encountered including unusually thick flanges at the horizontal joint in the turbine casing.

Advancements made in the last twenty-five years in turbine size, steam inlet pressure, and temperature along with reduction in heat rate are shown in Fig. 1.

Increase in Turbine Rating

In order to reduce the capital cost per unit of capacity, turbine designers have constantly striven to increase ratings. The capacity rating of the largest single shaft turbine-generators through the years is shown in Fig 1 for 1,800 and 3,600-rpm machines.

One limitation in connection with increasing the capacity of a condensing turbine is the annulus area of the low pressure exhaust blading. With a given inlet pressure and a fixed amount of extraction, the capacity can be increased without encountering prohibitive leaving loss by either using more than one exhaust or increasing the length of the last row blades. With a combination of these two methods, the size of 3,600-rpm units has been increased until now there are a number of 100,000-kw nominal-rated tandem-compound double-exhaust turbines with a 23-in. last row blade in operation. To improve efficiency at high vacuums, a few machines in this size have been provided with triple exhausts. The capacity limit today in individual 3,600-rpm machines has not been reached, some manufacturers offering to build still larger units.

Up to 100,000-kw nominal ratings, the 3,600-rpm TCDF (tandem-compound, double-flow) unit is practically standard now because of satisfactory operating characteristics, good efficiency, smaller physical dimensions and lower first cost. For ratings above 100,000 kw and up to approximately 160,000 kw and where inlet temperatures do not exceed 950 F the SC or SCTC 1,800-rpm unit is applicable. Because of the physical size of the 1800-rpm turbine casing, 950 F is now considered to be the maximum safe inlet temperature for these large machines. Units above a maximum capability of 125,000 kw and above initial temperatures of 950 F require cross-compound units having 3,600-rpm high pressure and 1,800-rpm low pressure turbines to obtain the highest turbine efficiency.

Feedwater Heating

An outstanding approach to the improvement in turbine heat rate which has had universal acceptance since 1924, is the practice of multi-stage feedwater heating with steam extracted from the main turbines at a number of points. Electrical energy generated by such steam is very efficiently produced because of the absence of condenser losses. Four and five stages

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Prepared by C. C. WHELCHEL, *Chief, Division of Steam Engineering, Pacific Gas & Electric Co* with the collaboration of members of the organizations of Allis-Chalmers Mfg Co, General Electric Co, Westinghouse Electric Corp, Foster-Wheeler Corp, Ingersoll-Rand Co and associates in the public utility field

of extraction are common today and as many as eight are being used. The theoretical improvement in thermal efficiency for an infinite number of stages of extraction for different pressures and temperatures is shown in Fig 2, while the table inserted on the chart shows the approximate practical gain for different numbers of stages.

In addition to improving the station efficiency and directly reducing the size of the surface condenser, extraction makes possible the increase in maximum turbine capacity that can be built. Output can be increased without prohibitive leaving loss only by decreasing the quantity of steam passed through to the exhaust end.

Early Pressure Limitations

Turbine throttle pressures in the early 1930's were still generally in the 400 to 600 psi range. The cast carbon steel materials for the cylinder limited the temperature to 750 F even though it was well known that the use of a higher temperature would result in a lower heat rate. It therefore was possible to consider only the increase in pressure. Higher pressure and low temperature in a straight-through condensing turbine increases the moisture at the exhaust end of the turbine. Experience generally indicated that blade erosion would not be excessive if the throttle conditions selected resulted in a moisture content of less than 12 to 14%. This meant that for any specific temperature there was a definite limit of pressure as shown in Fig 3.

Initial Use of Reheat

Although better metals were not available for temperature above 750 F, in the 1920's reheating could reduce the moisture content at the turbine exhaust and this cycle therefore was introduced in 1924. It permitted the use of higher throttle pressures at the maximum steam temperatures then allowable with a gain in thermal economy of approximately 5% with even less blade erosion than the then current practice because the moisture in the exhaust steam of a reheat turbine is less than 10%. Stations adopting the reheat principle were highly successful as evidenced by the drop in heat rate and the satisfactory performance.

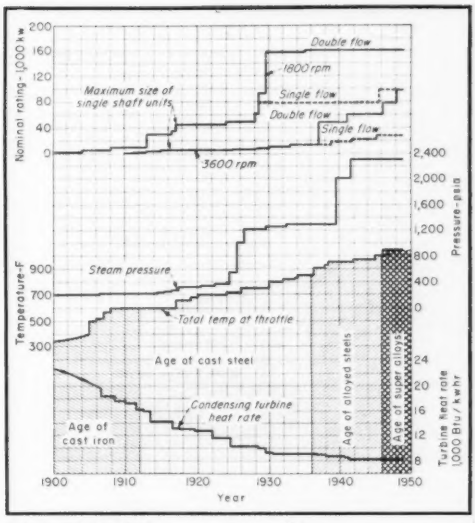

FIG 1—PROGRESS in operating conditions

Influence of Increasing Temperatures

Improvement in metals for higher temperatures continued, and since about 1935 there has been a steady increase in allowable steam temperatures. Each 25 F increase in temperature at constant pressure decreases the turbine heat rate approximately ¾%. With the gain in thermal efficiency obtained through the use of higher initial temperatures, most station designers felt that the additional cost and complication of reheat was not justified and for a period of almost fifteen years relatively few such installations were made. During this time new stations were generally designed for straight condensing units while superposed turbines were installed in a number of existing low pressure low temperature plants to increase the capacity and more particularly to improve the station heat rate.

Because of the urgent need for more capacity at the present time, almost no equipment is being retired which can be kept in service. There are indications

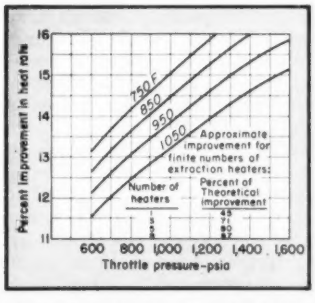

FIG 2—THEORETICAL IMPROVEMENT in heat rate for an infinite number of extraction heaters

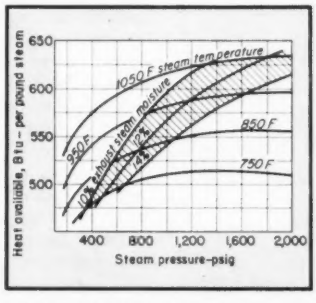

FIG 3—VARIATION in exhaust steam moisture content with pressure and temperature

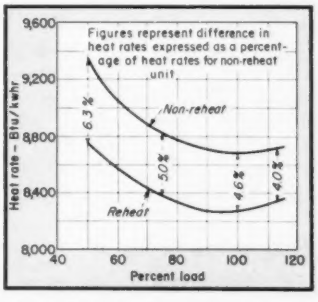

FIG 4—GAIN in economy results from reheat; improvement varies with the load on the turbine

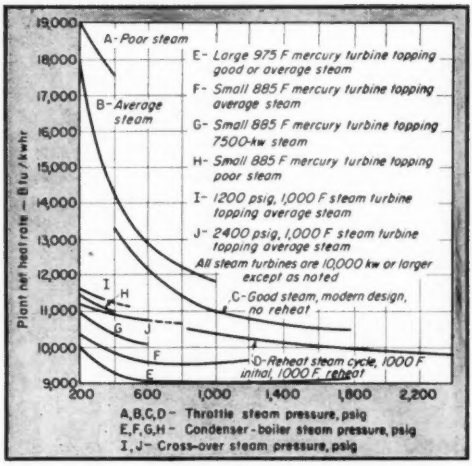
A- Poor steam
B- Average steam
E- Large 975 F mercury turbine topping good or average steam
F- Small 885 F mercury turbine topping average steam
G- Small 885 F mercury turbine topping 7500-kw steam
H- Small 885 F mercury turbine topping poor steam
I- 1200 psig, 1,000 F steam turbine topping average steam
J- 2400 psig, 1,000 F steam turbine topping average steam
All steam turbines are 10,000 kw or larger except as noted
C- Good steam, modern design, no reheat
D- Reheat steam cycle, 1000 F initial, 1000 F reheat
Plant net heat rate — Btu/kwhr
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
200
600
1,000
1,400
1,800
2,200
A,B,C,D - Throttle steam pressure, psig
E,F,G,H - Condenser-boiler steam pressure, psig
I, J - Cross-over steam pressure, psig

FIG 5—AVERAGE NET HEAT RATES compared for condensing steam-electric stations of various designs at different pressures with mercury steam cycles and high-pressure superposed steam-turbine cycles

however, that a revival of general interest in superposition will come after the present need for capacity is satisfied and as the older low pressure boilers approach retirement.

Improvement in Metals

Metallurgical developments which have permitted a steady increase in allowable steam temperatures with 1050 F as the maximum at the present time are the results of reasearch. For elevated temperatures there was required such additional information as creep or plastic flow, hot rupture, corrosion fatigue, grain size and susceptibility to graphitization. Energetic research is being carried on continuously to develop metals suitable for still higher temperature.

There were no unusual operating difficulties with the steels in use until about 900 F was reached. Then without warning serious trouble in the form of graphitization was encountered. Graphization is the reversion of the carbide of the steel to free graphite which results in a weakening of the metal. Addition of chrome will prevent graphitization.

Principal stabilizing materials which have been added to the steel are molybdenum, chromium, columbium, vanadium and nickel. The following generalization can only be taken as a rough indication of the suitability of different steels at the present time: Carbon steel up to 825 F; 1% chrome-moly for 950 F; 2¼% chrome-moly for 1,000 F and 18-8 stainless steel for 1,050 F and possibly 1,100 F.

Re-introduction of Reheat

Reheat received a marked revival of general interest about three years ago. Since that time thirty-five such units having a total capacity of over 3,000,000 kw have been purchased by public utility companies. Reacceptance of reheat is undoubtedly influenced by the increased cost of fuels and the generally higher steam plant load factors which have made it desirable to improve thermal efficiencies above those attainable with the non-reheat cycle. Another influence is the widely used single-turbine, single-boiler unit construction which has made possible the elimination of many valves and considerable piping.

Whereas the prime interest now in the reheat cycle is the gain in operating efficiency, twenty years ago reheating was introduced to limit moisture in the exhaust and permit use of higher pressures. Shown in Fig 4 is the thermal economy resulting from the use of this cycle in modern practice. Other advantages derived from reheat per unit output is the reduction in size of the boiler, condenser, feedwater heaters and related piping.

Standardization

In 1942 ASME and AIEE committees studied the problem of standardized turbines at great length. It was decided to limit standardization to 3,600-rpm condensing units (10,000-60,000 kw) of the single cylinder and tandem compound types. The four lower ratings of 11,500, 15,000, 20,000 and 30,000 kw have inlet steam conditions with pressures and temperatures representative of turbines purchased for each such capacity level. The 40,000 and 60,000-kw units have two optional steam conditions, 850 psig—900 F and 1250 psig—950 F. Fixed steam extraction points for feedwater heating are provided whether or not actually used.

Improvement in Design

Along with the numerous measures to increase the internal turbine efficiency have gone experimental investigations to improve reliability. With the exception of a few setbacks attributable to occasional epidemics of trouble, forced outages have decreased. The once-a-year scheduled shutdowns for inspection have gradually increased to once in two years with a tendency today to operate three or four years between inspections. There is reason to believe that even longer intervals are practical.

Lubricating Systems and Oil

With increased steam temperatures hazards from turbine lubricating oil fires increased and several cases of very serious fires occurred. As a result of such experience many units now have vulnerable high pressure oil pipes enclosed and great care has been taken in design to insure against breakage or leaks.

As turbine oils became more highly refined ten or fifteen years ago it appeared that some of the ingredients formerly present which allowed the oil to easily wet metal surfaces were either modified or were no longer present to the same degree. This contributed to a greater amount of rusting in the oil system and in some instances the oiling system had to be completely dismantled for cleaning. Today most turbine oils contain added inhibitors to minimize rust and oxidation.

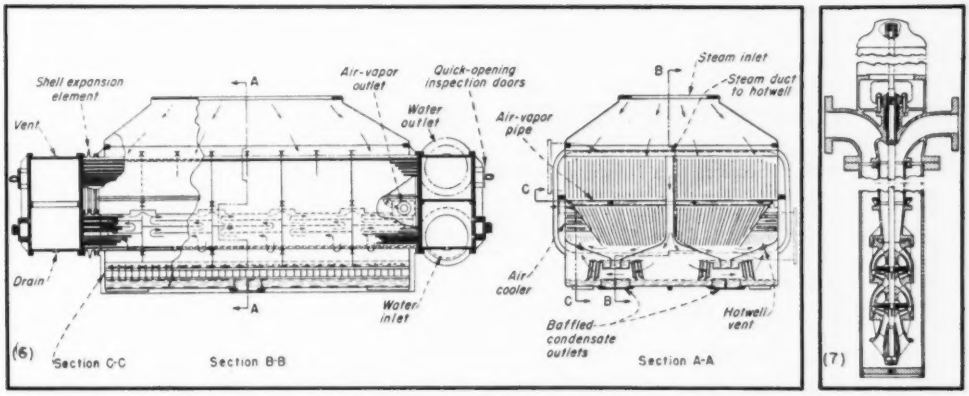

FIG 6—STEAM FLOW in a modern condenser. FIG 7—VERTICAL CONDENSATE PUMP

Turbine Governing

Increasing steam pressures and temperatures and rotor speeds through the years have produced a reduction in the turbine rotating inertia per kw capacity. As a result the rotor acceleration rate has increased, which in turn requires faster operation of the steam valves for satisfactory governing. These and other considerations have resulted in the development of faster and more powerful control equipment not only for ordinary governing, but also to insure that with a sudden loss of full load on a machine the operating governor is fast enough to prevent the emergency overspeed from tripping thereby enabling load to be more quickly reapplied to the machine.

Turbine Deposits

Even though the purity of steam from a modern boiler is very high a number of high pressure turbines have been subject to a deposition of solids on the rotating and stationary blading or nozzles and on valve stems. This material is carried over from the boiler, probably in a vapor state, and condenses out in the turbine thereby reducing its efficiency and its load carrying ability. Some deposits are soluble in water and can be washed off with turbine load changes while others containing silica can only be removed with a caustic wash or by removing the rotor and employing mechanical means.

Turbine Supervisory Instruments

Supervisory instruments have made possible not only more reliable turbine operation, but in many cases they will give warning of the development of turbine mechanical trouble. Such instruments were first installed commercially in 1932. Equipment is now available to record shaft eccentricity, shaft vibration, spindle position, bearing vibration, shell expansion, speed and camshaft position.

The binary cycle, using mercury as the first vapor and steam as the second, has a higher thermal efficiency between the same temperature limits than the straight steam regenerative cycle. Shown in Fig 5 are representative plant net heat rates available from steam and from mercury-steam cycles for condensing plants.

A 10,000-kw mercury plant was placed in operation in 1928 in the South Meadow Station at Hartford. In 1933 one 20,000-kw mercury turbine was installed at Kearny and another at Schenectady. Two "standard" 7500-kw mercury turbines and condenser boilers for supplying steam to one 25,000-kw steam turbine are now being constructed for the Public Service Co of New Hampshire. The problem of wetting boiler tubes with mercury is now believed to be solved and current mercury installations may prove this cycle to be more economical and as reliable as the straight steam cycle.

Gas Turbines

Because of the over-all simplicity of a gas turbine power plant, considerable interest has been shown in this equipment in recent years. In public utility power plants the greatest usefulness for some time to come appears to be for low load factor plants in locations where oil or gas is an economical fuel and condensing water is limited. Ultimately pulverized coal may be burned, but such a development is still in the future.

A 3500-kw simple-cycle gas turbine-generating unit is now being built for the generation of electric power in a southwestern public utility plant with natural gas as a fuel. Although the gas turbine unit alone will have an efficiency of approximately 17%, exhaust gases will be used for heating feedwater in the existing steam plant. Cost per kilowatt of capacity is understood to be comparable with a steam generating unit.

Thermal efficiency of gas turbines varies from approximately 15 to 30% depending on the initial temperature and the degree of regeneration and inter-cooling which can be justified. A unit rated 15,000 kw with a guarantee similar to that given for steam turbine-generators is under design for an inlet temperature of 1,300 F. Gas turbine installations will continue to be watched with interest in order to weigh the many factors involved including reliability, cost, efficiency and expected life. That they will find a place in the electric

power generation field is reasonably certain.

Surface condensers have increased in size as the turbines have increased in capacity, but the increase has not been nearly in proportion. The use of higher initial steam pressures and temperatures, the increase in the amount of steam extracted from the turbine for feedwater heating and the improved internal efficiency of the turbine have all resulted in a reduction in the amount of heat rejected to the condenser per kw generated. Condenser tube surface has on an average decreased from about 1.6 sq ft of surface per kw of turbine capacity, which was common twenty-five years ago, to a present day figure of approximately 0.8 sq ft per kw. A portion of the reduction may be attributed to improvements in condenser design which have permitted the use of higher heat transfer rates.

Heat Transfer Rates

A typical heat transfer rate obtained in 1924 was 350 Btu, whereas the average heat transfer rate for condensers of today is in the order of 576 Btu per sq ft per degree logarithmic mean temperature difference per hour, a result of putting more tube surface effectively to work. Sluggish surface has been minimized for the sake of a higher average heat transfer rate.

Improved distribution of steam to all surfaces has been evolved by the careful patterning of tube sheets and the use of baffles and steam lanes. Shown in Fig 6 is the flow in a typical modern condenser.

Condenser Tubes

In 1924 the practice was to pack tubes at both ends. The use of tubes rolled at one end and packed at the other was introduced prior to this time, but the purpose was to improve water flow and reduce corrosion at the inlet ends. The design trend is toward the use of tubes rolled into the tube sheets at both ends with provision for expansion by the use of expansion joints in the shell or bowed tubes which reduces leakage between the tubes and the sheets to a minimum. With the boiler pressures that are being employed today, this is of considerable importance.

Approximately 45% of the condensers currently being supplied are equipped with Admiralty tubes, arsenical-copper is used on approximately 30%, aluminum-brass on 15% and the balance have miscellaneous cupro-alloy tubes. Muntz metal is being used almost universally for tube sheets.

Deaerating Hotwells

In 1924 an oxygen content of 0.1 cc per liter in the condensate leaving the hotwell was considered good practice. Some manufacturers have perfected deaerating hotwells to a guarantee as low as 0.01 cc per liter.

It is common for condensers today to produce condensate temperatures from 0 to 2 F greater than the exhaust steam temperature, a direct result of reducing the pressure drop across the steam side of the condenser between the exhaust inlet and the hotwell. Even with light loads and low circulating water temperatures it is unusual to get more than 1 F refrigeration of the condensate with present day condensers. In the late Twenties and early Thirties 10 F refrigeration was common.

There appears to be a trend at this time to the separation of the condenser hotwell into two sections so that the salinity of each section can be checked independently. This permits an immediate determination of which half of the condenser has a leaking tube that increases the salinity of the condensate.

Condenser Shells

Construction of welded condenser shells was introduced about 1930. This permitted greater flexibility of shell design to suit restricted spaces, has made it possible to weld the condenser neck to a steel turbine lower exhaust half casing which eliminates a potential point of air leakage and has tended to reduce cost. In 1929 the first extraction heater was installed in a condenser neck. This procedure is being viewed with increasing interest on large capacity installations utilizing tandem multiple flow low pressure turbine arrangements as it appears to result in an economical, compact installation. Where this type of turbine is used it is now common practice to bring low pressure extraction lines out through the exhaust neck of the condenser.

Waterboxes

Waterboxes on condensers for large turbines are still commonly made of cast iron or its elementary alloys, as this material has been found to resist corrosion to a degree commensurable with its cost.

The divided waterbox, which was introduced early in the 1920's has met with wide acceptance. By its use it is possible to clean one-half of the condenser while the turbine remains in operation on the other half, generally at about two-thirds maximum load.

Conclusions

The size of condensers for a given duty has been substantially reduced in the last twenty-five years by improved arrangments of internal parts. This, together with vertical pumps has tended to reduce station head room and space requirements. Condenser and turbine manufacturers along with power plant designers have collaborated to produce variations of condenser and turbine arrangements to further reduce plant costs which may eventually lead to the general use of the condenser to support the turbine. There are indications that in the future all deaeration will be done in the condenser thereby eliminating the separate deaerating heater.

The largest future gains to be made in steam turbine thermal efficiency lie in the direction of still higher steam temperatures than those in use at the present time and at pressures in the range of 1,800 to 2,400 lb. It seems fairly evident therefore that further improvements will be obtained in this manner. Known research programs now in progress include tests on Austenetic alloys up to 1,600 F. The pause for steam turbine operating experience at 1,050 F may prove to be relatively short.

Excitation and Auxiliary Systems

Almost exclusive use of motor-driven auxiliaries. Influence of system characteristics. Adjustable speed drives. Generators and transformers as sources. Back up provisions. Issue of exciter speed. Rotating regulators

THROUGHOUT THE HISTORY of steam power plant development the integrity of the station auxiliary power supply has always been considered of primary importance to the reliability of station operation. Twenty-five years ago two factors probably governed the employment of certain steam-driven auxiliaries, namely: (1) The need for exhaust steam for boiler feed makeup; and (2) lack of confidence in the station auxiliary electric power system. The first item has now been disposed of by providing bleed points in the turbine, and the second is rapidly disappearing, as will be brought out in the following discussion.

Mid-twenties Philosophy

Twenty-five years ago a new pulverized coal-burning steam power station was constructed near St. Louis, Mo., designed so as to incorporate all the then conceived precautions for economical and reliable operation. It had two 35,000-kw, 1,800-rpm steam-turbine driven air-cooled generators with direct-connected exciters, using generator field rheostats. It employed some steam-driven boiler feed pumps. The rest of the auxiliaries were motor driven, and the bulk of the power supply was derived from the 13.8-kv system bus. To protect essential auxiliaries against system disturbances, two 2,500-kw, 2,300-v non-condensing steam-turbine driven house generators were installed. These generators were connected to a special 2,300-v bus from which the so-called essential motor-driven auxiliaries were supplied with their power. This special 2,300-v bus, for essential auxiliaries, was connected to the 2,300-v station auxiliary bus supplied from the 13.8-kv system bus through saturated core reactors, the latter to prevent the auxiliary turbine-driven units from picking up system load. The principles employed in that particular station are not far removed from some of the present-day practices.

Influence of Feed Heating

Just prior to the construction of the above mentioned plant other stations had stoker-fired boilers and made liberal use of steam-driven auxiliaries on boiler-feed pumps and vacuum pumps. Steam-driven exciters were usually supplemented by motor-driven exciters. These exciters fed a common station excitation bus which was backed up by a large storage battery capable of supplying excitation for all of the alternators of the station for some minutes in an emergency.

Present-day employment of several bleed points on modern steam turbines provides adequate steam for feed-water heating, evaporator condensers, etc, and thus helped to depopularize the use of steam-driven auxiliaries.

Auxiliary Supply System

Twenty-five years ago, as now, power (five to seven percent of generator output) for electrically-driven auxiliaries was derived from the station bus and also from the outside system. The character of the outside system has an important bearing on the reliability of the station power system.

Outside systems can be considered as falling into two classes: (1) The closely linked system; and (2) the loosely linked system.

1. The closely linked system is one in which steam power stations in a concentrated area are interconnected by high-voltage underground cable ties, usually 69 kv, either directly or through bulk power substations which receive their power from several sources. Usually such a system has a number of high-voltage overhead interconnections with external sources of power.

2. The loosely linked system is one of widespread area in which the power stations on the system are not connected by high-voltage underground ties within the system, but which may have one or more overhead line interconnections with external systems.

The metropolitan power systems of New York, Chicago, and Philadelphia fall within the definition of the closely linked systems.

On the other hand, Baltimore, Pittsburgh, Newark, Minneapolis, and St. Paul fall within the definition of the loosely linked systems.

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with collaboration of N. E. Funk, Philadelphia Electric Co; C. A. Corney, Boston Edison Co; G. A. Armbrust, Commonwealth Edison Co; V. E. McCallum, Commonwealth Edison Co; E. H. Snyder, Public Service Electric & Gas Co

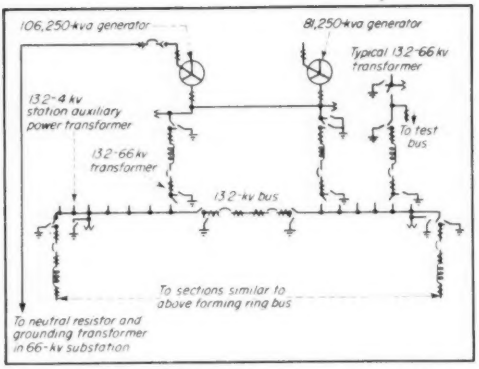

106,250-kva generator
81,250-kva generator
Typical 13.2-66 kv transformer
13.2-4 kv station auxiliary power transformer
To test bus
13.2-66 kv transformer
13.2-kv bus
To sections similar to above forming ring bus
To neutral resistor and grounding transformer in 66-kv substation

FIG 1—MAJOR CONNECTIONS for one of two 150,000 kw cross-compound units in Southwark Station

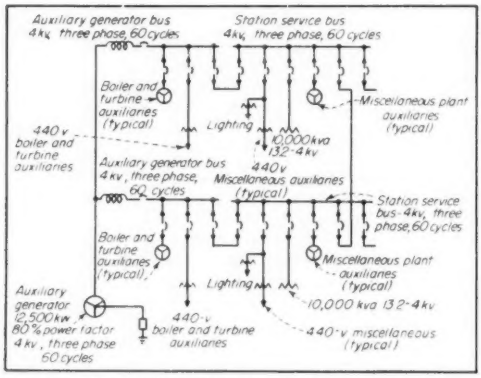

Auxiliary generator bus 4 kv, three phase, 60 cycles
Station service bus 4 kv, three phase, 60 cycles
Boiler and turbine auxiliaries (typical)
Miscellaneous plant auxiliaries (typical)
Lighting
10,000 kva 13.2-4 kv
440 v boiler and turbine auxiliaries
Auxiliary generator bus 4 kv, three phase, 60 cycles
440 v Miscellaneous auxiliaries (typical)
Station service bus 4 kv, three phase, 60 cycles
Boiler and turbine auxiliaries (typical)
Miscellaneous plant auxiliaries (typical)
Lighting
Auxiliary generator 12,500 kw 80% power factor 4 kv, three phase 60 cycles
440 v boiler and turbine auxiliaries
10,000 kva 13.2-4 kv
440-v miscellaneous (typical)

FIG 2—AUXILIARY POWER SUPPLY derived from one of two 12,500-kw auxiliary generators in Southwark Station

Adjustable-speed Drives

One of the knottiest problems to confront earlier station designers was the obtaining of adjustable speed for certain drives such as fuel feeders, and forced and induced-draft fans, air preheaters, boiler feed pumps, etc. Twenty-five years ago wound rotor induction motors, repulsion induction motors, and even thyratron motors were applied on fan drives. All of these types proved vulnerable to boiler-room atmosphere and high temperatures and were a source of constant trouble. In some stations adjustable speed direct-current motors were employed, but these were in the minority.

During the past twenty-five years variable-speed couplings, both electrical and mechanical, have been developed which eliminate the need for adjustable speed motors, and permit the use of simple, rugged squirrel cage induction motors. Also, the fan manufacturers have developed the vane control which even eliminates the adjustable speed coupling. It remains to be seen whether the vane control will prove as flexible and reliable as some of the present adjustable-speed couplings.

Variable speed electro-magnetic couplings of 400 and 800 hp with forced and induced-draft fan drive, respectively, as initially built ten years ago proved exceedingly troublesome. They were provided with two pedestals each with an internal roller bearing. Bearing weaknesses plus inadequate design of the rotor bars of the squirrel cage winding resulted in failures of these couplings.

One further improvement made recently has been the employment of an electronic exciter for the magnetic coupling, and this with its accessory devices results in this coupling following the air needs of the boiler most faithfully.

Hydraulic couplings seem to meet with favor with some station designers. The operation of vane control will be watched with considerable interest.

Prevailing Practice

The following methods are currently being used to derive electric power supply for station auxiliary service:

1. From the station generator bus and so from the system.
2. From steam-driven station auxiliary generator in addition to No. 1.
3. From shaft driven generators plus No. 1.
4. From transformers connected directly to the generator leads in combination with No. 1.

In starting up a new station or one that has been shut down for any cause, power for starting up motors must be obtained from the system.

Whether the station bus and system are dependable as the sole source of station auxiliary power depends: (A) Upon the character of the system; (B) the judgment and experience of the designers and operators.

Close-link System Stations

The Chicago and Philadelphia metropolitan systems both fall within the category of closely linked systems. Substantially the same problems with respect to station auxiliary power supply therefore confronted the designers of both the Southwark Station and the new station for Chicago.

Shown in Fig 1 are the connections of one of the two 150,000-kw cross-compound turbine-driven generators to the system and the supply source for station power for Southwark Station.

Shown in Fig 2 are connections for the station auxiliary power buses for one unit.

Principal dependence during normal operations is placed upon two 12,500-kw, 4-kv, 3,600-rpm steam turbine driven station auxiliary generators. Normally, the exhaust steam from these generators is delivered to a bleed point on the main steam turbine units. For operation independent of the main turbine units, each of the auxiliary generators is provided with a special condenser.

The station auxiliary buses (Fig 2) operate at 4 kv supplied by the auxiliary generators at this voltage; principal station auxiliary motors are also 4-kv units. Smaller station auxiliary units are 440-v units.

A new station for Chicago is now under design and construction of the same capacity as the Southwark Station and employing the same general combination

of prime movers. Power for station auxiliaries will be taken from the 69-kv system, and will be supplemented by connections from the generator leads. The Chicago bulk power supply system is operated at 69 kv, and underground circuits are arranged in two groups known as the "Red" and "Blue" networks.

Represented in Fig 3 in abbreviated form are the connections of one of the 150,000-kw dual units to the 69-kv system and the connections from this generator to the station auxiliary buses. There will be two boilers 700,000 lb, 1,800 psi for each turbine unit, but the connections are shown for only one.

Auxiliary Bus

The station auxiliary principal supply bus is arranged for 4 kv operation. For boiler No. 1 of Unit No. 1 connection is made to one end of the bus through a 6,000/8,000-kva, 69 kv/4.16-kv transformer unit from the "Red" network ring bus; the other end of this bus is supplied by a same size transformer except fed directly from the generator leads.

For boiler No. 2 of Unit No. 2 the bus supplied is supplied from the 69-kv, "Blue" ring bus.

Southwark and the Chicago Station both deliver to the 69-kv systems and no power is sent out at generator voltage.

The 208/120-v network (Fig 4) for smaller motors is obtained for the Chicago Station from the 4-kv bus. One end of this bus is supplied from the 69-kv "Blue" ring bus and the opposite end supplied from the 69-kv "Red" ring bus.

The Chicago plant will thus place its principal dependence for station power on the system bus without the use of auxiliary generators.

Generator Leads as Source

In 1930 a new station in the Pittsburgh area was arranged to take the station auxiliary supply for the 2,300 and 440-v motors from the station bus. In addition a station auxiliary transformer was connected to the generator leads with an intervening oil circuit breaker.

In general, all the principal auxiliaries for the station were in duplicate. One auxiliary was connected to the station auxiliary bus supplied from the station and the duplicate auxiliary to the bus supply from the transformer connected to the generator leads.

Shaft-driven Auxiliary Generator

In the case of a new station in Pittsburgh, constructed in the early 1940's, decision was reached to employ a shaft-driven 2,300-v generator of approximately 10% of the capacity of the main generator for operation of at least one-half of the essential auxiliaries of the station. In this station also the principal auxiliaries were in duplicate.

Shown in Fig 5 is the basic scheme of connections of the transformer supply from the outside 22-kv system and from the house generator. Half of the auxiliaries are connected to Section A of a two-section bus and the other half to Section B.

The system transformer and the house generator

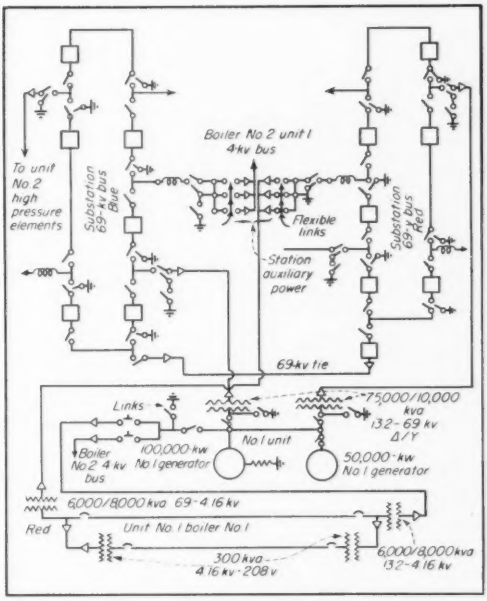


FIG 3—TYPICAL 4-kv station auxiliary power supply derived from bus or generator leads for new station in Chicago area

are each provided with selector switches that connect to the two bus sections. It is impossible to parallel the house generator with the system supply. In the act of closing a generator breaker to one of the bus sections the corresponding breaker from the system transformer is automatically tripped off. Thus the house generator picks up the load of that section. No difficulty has been experienced with this method of operation. Some difficulty has been experienced elsewhere, due to residual flux in the motor cores which necessitates a time delay in the throwover.

Paralleling for Transfer

When the present program is completed on the Minneapolis-St. Paul system there will be four 2,400-v house generators each connected to a 60,000-kw main generator. From the standpoint of switching reliability, interlocking control on circuits, etc, the operators considered that it was desirable to parallel the house generator momentarily with the system during the period of transfer.

Such a procedure results in certain complications which, however, are not of serious consequence. Obviously, since the house generator is operated by the same prime mover with the main generator, the house generator will tend to pick up its share of the system load depending upon the setting of the field rotor of the house generator with respect to the main generator rotor. To provide for adjustment of this situation and to procure the best operating results the manufacturer has provided the coupling between the house generator and the main generator with 8 bolt holes in half of the coupling and 16 in the other half. This

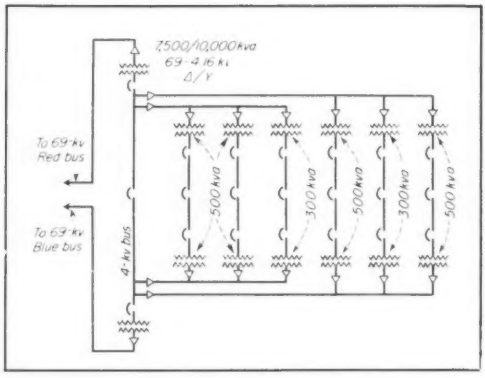


FIG 4—NETWORK auxiliary power supply (208/120 v) for new Chicago station is obtained from the 4-kv bus

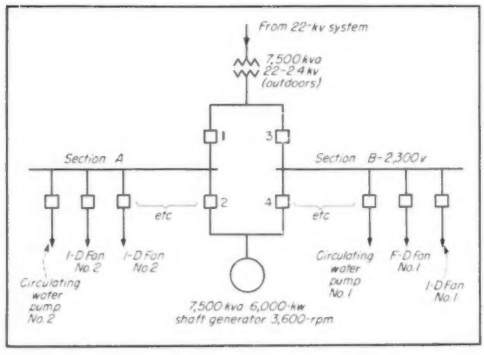


FIG 5—23 KV AUXILIARY power system for one 65 Mw unit in Phillips Station in Pittsburgh area. Shaft generator not paralleled with system because of interlocking of breakers prevents simultaneous closing of 1 and 2 or 3 and 4

permits rotating the rotor of the house generator by 22½ deg in either direction.

To take care of the eventuality of loosely-linked systems breaking apart the house generator appears to be a logical solution to maintain operation of the principal auxiliaries independent of system disturbances, and so prevent a shutdown of the station.

Pros and Cons

Comment has been made by some that the employment of the shaft generator either with or without shaft-driven exciters may result in shutting down the main unit. The answer is that there are many other "gadgets" associated with large steam turbines which may be the cause of a shutdown. Generally speaking, the shaft generator is not subjected to system surges, lightning, etc, and the likelihood of its getting into trouble seems very remote.

Comment has also been made that the shaft generator takes up valuable space in a station, necessitates additional building, and is more costly than other methods of supply. The answer to this comment is that the space taken by the shaft generator, main exciter, shaft generator exciter and pilot exciter is not greater than the space required to remove the main generator field, hence no additional building cost is involved.

Dead Throw-over

A 100,000-kw, 3,600-rpm steam turbogenerator was recently installed (ELECTRICAL WORLD, March 26, 1949) in Essex Station in Newark, New Jersey, supplied from a 900,000-lb per hour, 1,250-psi boiler. The new unit and its boiler are entirely independent of the older part of the station except for connections to the system for starting up the new unit.

The various auxiliaries associated with the new unit are all motor-driven. The power for starting up is obtained from a 13.2 2.4-kv, 4,000-kva transformer connected to the older station generator bus. When the turbine is up to speed, these auxiliaries are switched "dead" over to a bus supplied by a 7,500-kw, 2,400-v shaft-driven house generator connected to the main new unit.

While the Louisville system conforms to the definition of a loosely-linked system, given previously, there are several external interconnections with Paddys Run Station (Fig 6). It was considered that transformer supply was adequate for auxiliary supply.

Connections for station auxiliary supply for Unit No. 1, 35,000 kw, and Unit No. 2, 60,000 kw, at Silver Gate Station, San Diego, California are shown in Fig 7. One station auxiliary transformer is connected to generator leads through generator ring bus. This also is a loosely linked system but with external connections.

Excitation Systems

Twenty-five years ago shaft-driven generators and pilot exciters were not in use. It was not uncommon to employ a common excitation bus to which all of the alternator fields were connected through circuit breakers. Voltage and reactive control of the main generators was obtained by means of remote control motor-operated rheostats connected in the main generator field circuit. The excitation bus was energized by steam-driven exciters, motor-driven exciters and even by three-unit steam-motor driven exciters. In some cases a substantial storage battery was employed for back up. These arrangements were, however, usually carry-overs from earlier periods.

The principal difficulty found with the above mentioned common excitation bus was that a ground on any field or any other circuit connected to the bus meant a ground on the bus. If this ground occurred on the field circuit it was customary to isolate this generator from the excitation system and carry it on a separate motor-generator set until such time as repairs could be made. This difficulty led the way to present developments.

Shaft Exciter

Beginning about twenty-five years ago the shaft-driven exciter, supplemented by a motor driven reserve exciter for two or more units, began to be used. At

this stage of development the main generator operated at 1,800 rpm, was of approximately 30,000 kw in size, did not involve the use of a large exciter, and no particular exciter commutation trouble developed. In general, the alternator field rheostat still persisted and manual control of the generator voltage was in general use. Some few systems had automatic voltage regulators. In due course the pilot exciter put in an appearance and replaced the clumsy power-consuming generator field rheostat.

Introduction of 3,600 rpm steam turbine units with shaft-speed exciters and pilot exciters paved the way for more exciter troubles. As long as the main exciter capacity did not exceed 100 kw, no particular troubles occurred. As units increased in size, however, to 60,000 kw, 3,600 rpm, requiring 250-kw exciters, commutation troubles began.

Varying Advocacies

One manufacturer builds and recommends shaft speed (3,600 rpm) exciters, even up to 350-kw capacity, and for 375-v operation.

An exciter driven by a 550-v, 1,200-rpm motor has been installed with Unit No. 4 in the Edgar Station in Boston. This unit, however, has a 285-kw, 375-v, 3,600-rpm shaft-speed exciter and pilot exciter.

A second manufacturer has adopted the use of geared exciters operating at approximately one-half the main shaft speed for exciters of over 100 kw. The third manufacturer recommends gearing or motor-generator sets for the larger units.

This divergent situation has existed for the past eight years.

Voltage Control

That all operators still do not favor either geared or shaft speed exciters is evidenced by the installations at Riverside Station, Baltimore, the new unit at Essex Station in Newark and the new Chicago Station. All of these stations employ motor-generator sets, which are equipped with Amplidyne or Rototrol voltage controls.

Each of the four generators at Southwark Station is provided with a shaft-speed main exciter, pilot exciter and automatic voltage regulator. A motor-driven exciter provides: (1) Excitation for starting since field current is necessary for both machines before turning over and (2) availability of a spare exciter to take the place of any shaft-driven exciter.

Rotating Regulators

With the first cross-compounded turbine unit to be installed in the new Chicago Station there will be employed three 300-kw, 1,200-rpm motor-generator exciter sets, each equipped with a flywheel to carry the exciter over momentary dips in the supply voltage. These units will each be equipped with a Rototrol pilot exciter. One motor generator set will be connected to each of the two generators of the turbine unit and the third motor generator will be a spare.

Thus the designers and operators of the Riverside Station, Baltimore, the new Essex unit, Newark, and the new Chicago Station apparently have frowned on shaft-driven (either geared or shaft-speed) exciters for their stations.

Practically all the new turbo-generator units currently under construction for installation in the near future are to be equipped with either Rototrol or Amplidyne voltage control devices and employ stabilized main exciters.

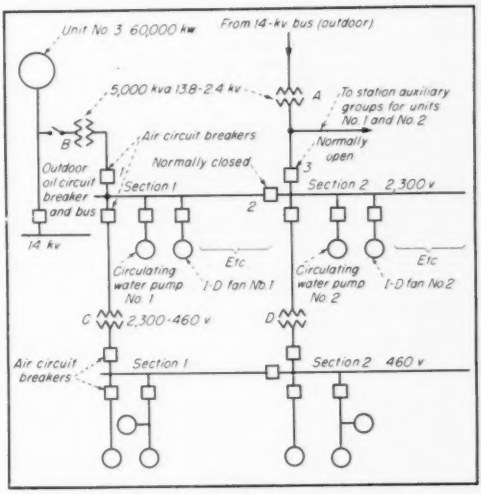


FIG 6—STATION AUXILIARY SYSTEM at Paddy's Run Station, for one 60 Mw generator on interconnected system

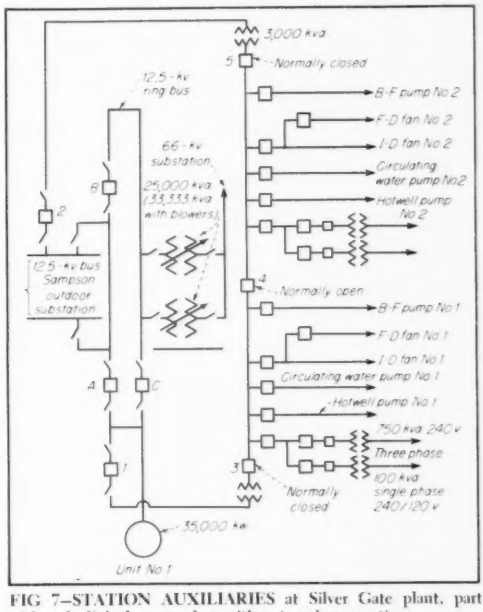


FIG 7—STATION AUXILIARIES at Silver Gate plant, part of loosely linked system but with external connections

Reserve Exciter Sets

Where a station employs two or more turbo-generator units, particularly if the latter is equipped with shaft-driven exciters, it is customary to have a reserve motor-driven exciter.

If the main turbo-generators employ shaft driven main exciters and pilot exciters or if they have an exciter for a shaft auxiliary generator, then this motor-generator set should have the same number of exciters as the main unit, and should be of adequate capacity to handle any one of the units in the station. Whether or not this reserve exciter set should be equipped with a flywheel depends upon the judgment of the individual operator and designer.

Parallel Transfer

There are two schools of thought on how this reserve generator should be substituted for the shaft exciter. One school is that this reserve exciter should be capable of being paralleled with the shaft exciter before the shaft exciter is disconnected (Fig 8). A double-throw circuit-maintaining switch with resistors on two upper and lower contacts is employed.

The second school holds that exciter troubles are not usually of an emergency nature, and that it is possible to wait until the load can be removed from the main generator so that this exciter may be disconnected and the reserve exciter connected in its place through suitable circuit breakers. The method is illustrated in Fig 9.

Station Auxiliary Power

There is thus no unanimity on the part of designing and operating engineers as to the preferred method of arranging station auxiliary electric power supply. Under quite similar conditions, two sets of designers have contemporaneously employed totally different methods. About the only things that are universally accepted for station auxiliary power supply are the following:

1. Power for starting up a new station should be obtainable through transformers from the outside system.

2. Development of the squirrel-cage motors for full-voltage starting in all used sizes, even up to 3,500 hp has been instrumental in eliminating steam-driven auxiliaries. Improvement in the stator windings for various atmospheres and temperatures, and development of frames for drip-proof and splash-proof operation, and even totally enclosed with fan cooling, water tube cooling, etc, makes this type of motor entirely suitable for all constant speed operation. It is also widely used for operating adjustable-speed auxiliaries in conjunction with magnetic or hydraulic couplings.

3. With improved reliability of station auxiliary power supply it is possible to employ practically all motor-driven auxiliary equipment.

4. Station auxiliary power systems as simple as possible and with a minimum number of breakers.

There does not exist uniformity in the selection of voltages for station auxiliaries:

208-120; 240; 460; 575; 2,400 and 4,160-v three-phase supplies have been used, but not more than two in the same station.

Excitation

There is manifestly a divergence of opinion as to the best way to provide excitation supply. A number of operators still have no faith in the reliability of the shaft-driven exciters, whether at shaft speeds or at lower speed through gearing. These operators have all selected motor-driven exciters, some with flywheel.

There is currently a general trend of all operators of large units to favor the use of rotating regulator control of excitation voltage and so the main generator voltage.

Exciter voltages for large generators are going to 375 v or even higher.

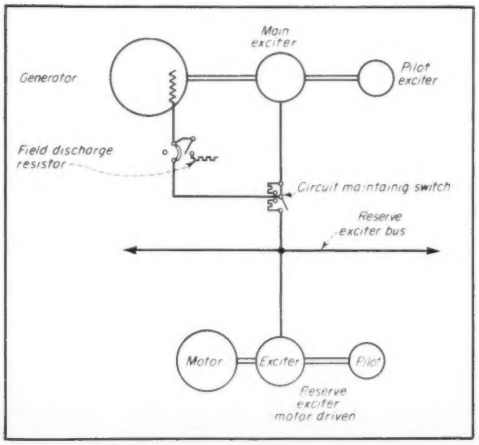


FIG 8—RESERVE EXCITER for paralleling with shaft exciter for changeover using a double-throw, circuit-maintaining switch

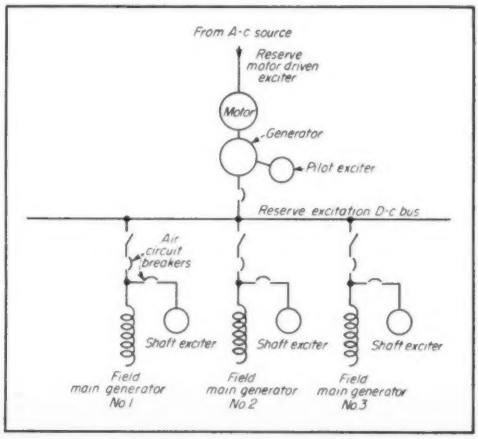
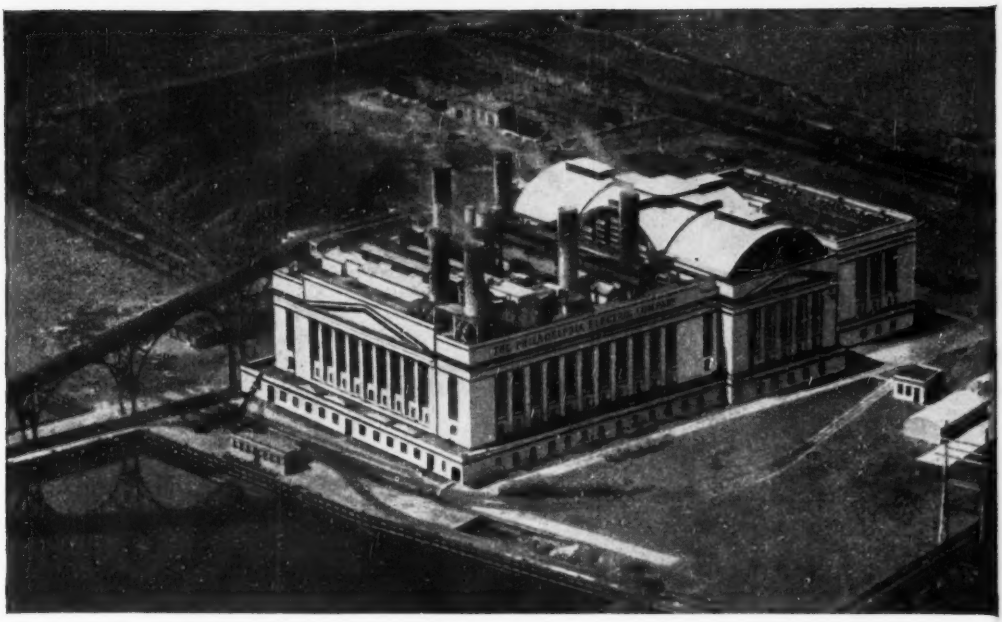
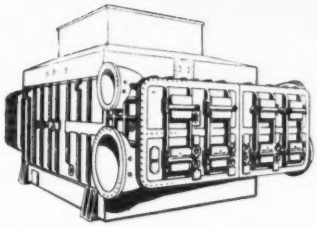


FIG 9—RESERVE EXCITER arranged for throwover with load removed from generator is a method used in some stations

PHILADELPHIA ELECTRIC CO. TO INSTALL 75,000 SQ FT CONDENSER





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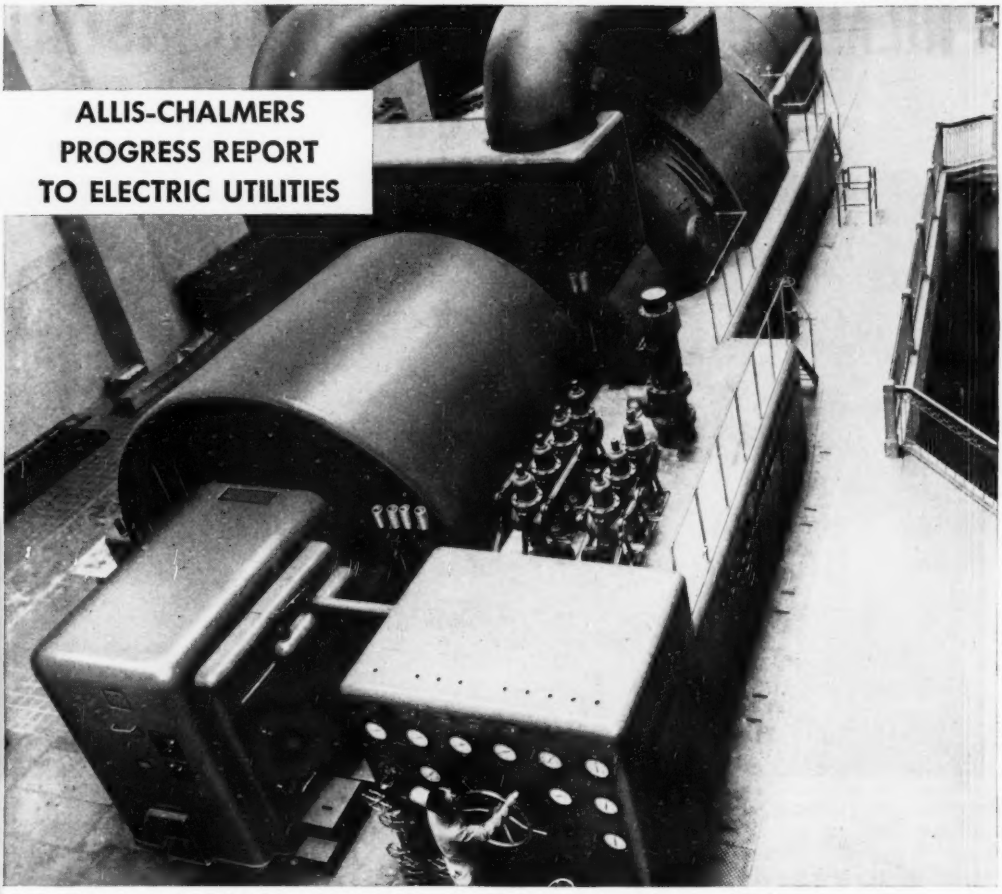
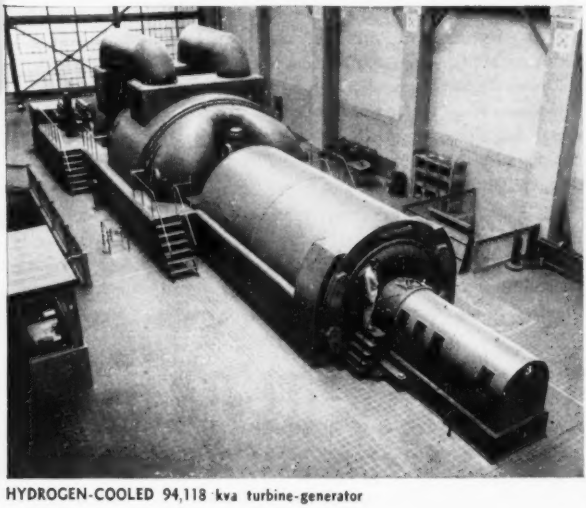
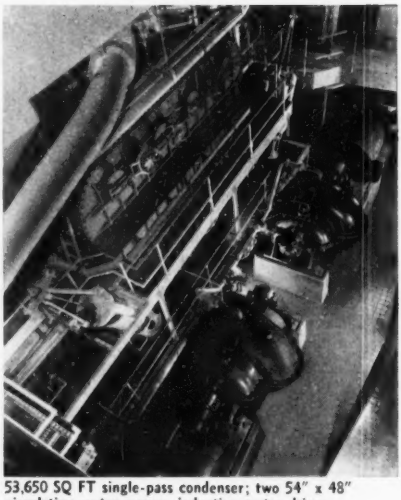


80,000 KW REHEAT TURBINE-GENERATOR operates at 1290 psig and 850 F at throttle, with reheat to 850 F.



HYDROGEN-COOLED 94,118 kva turbine-generator



53,650 SQ FT single-pass condenser; two 54" x 48" circulating water pumps, induction motor drives

Record KW Allis-Chalmers Turbine-Generators Shipped

WHILE THIS PAST YEAR has seen many records set in Allis-Chalmers' varied lines of electrical and heavy industrial products, none have been more significant than those set in power generating equipment. More kilowatts of steam turbine-generator units were shipped than in any previous year!

STEAM TURBINE-GENERATOR UNITS drive nearly 70% of the nation's electric generators. And they command extensive design and productive facilities at Allis-Chalmers where turbine-generator units in all ratings are manufactured. Current production includes condensing, non-condensing and automatic extraction turbines.

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Every type of regenerative steam cycle as well as the reheat cycle are involved in current production and development.

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To meet advancing requirements, a conservative application of many new principles in turbine and generator design now in current manufacture will greatly benefit the utilities. These new units are obtainable particularly in ratings from 10,000 kw to the largest.

Our current year marks Allis-Chalmers' forty-sixth in the manufacture of steam turbine-generating units—80th in steam prime mover manufacture.

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SURFACE CONDENSERS. Allis-Chalmers importance in the condenser industry was reflected in shipments totalling approximately ¾ million sq. ft. of complete condensing plants in 1948, varying in size from 1000 to 70,000 sq. ft.

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Our shipping schedule for 1949 shipments exceeds this figure and includes units of 100,000 square feet cooling surface. These condensing plants are complete with all auxiliaries of A-C manufacture, including pumps, motors, and steam jet air ejectors.

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Since 1869 and the dawn of the famed Reynolds Corliss engine, Allis-Chalmers has been a leader in steam prime movers. Since 1880 we have built many millions of square feet of condensers.

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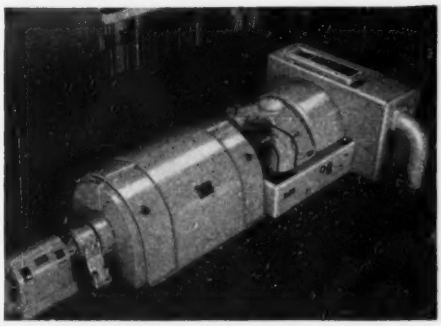
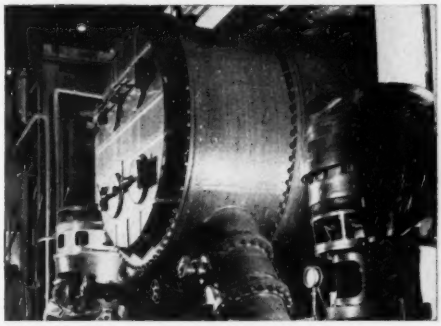
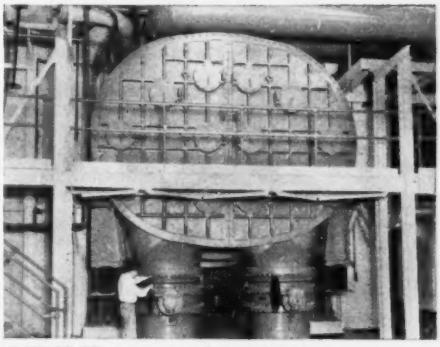


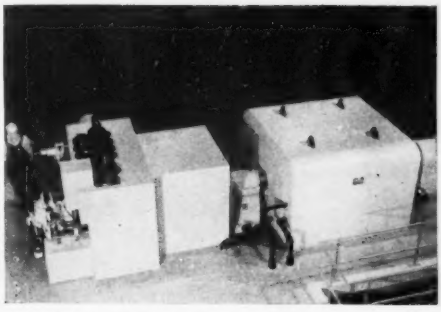
10,000 KW UNIT, 850 psig, 900 F, 1" Hg abs



15,900 SQ FT single-pass condenser; 2 circulating water pumps, motors



50,000 SQ FT single-pass surface condenser



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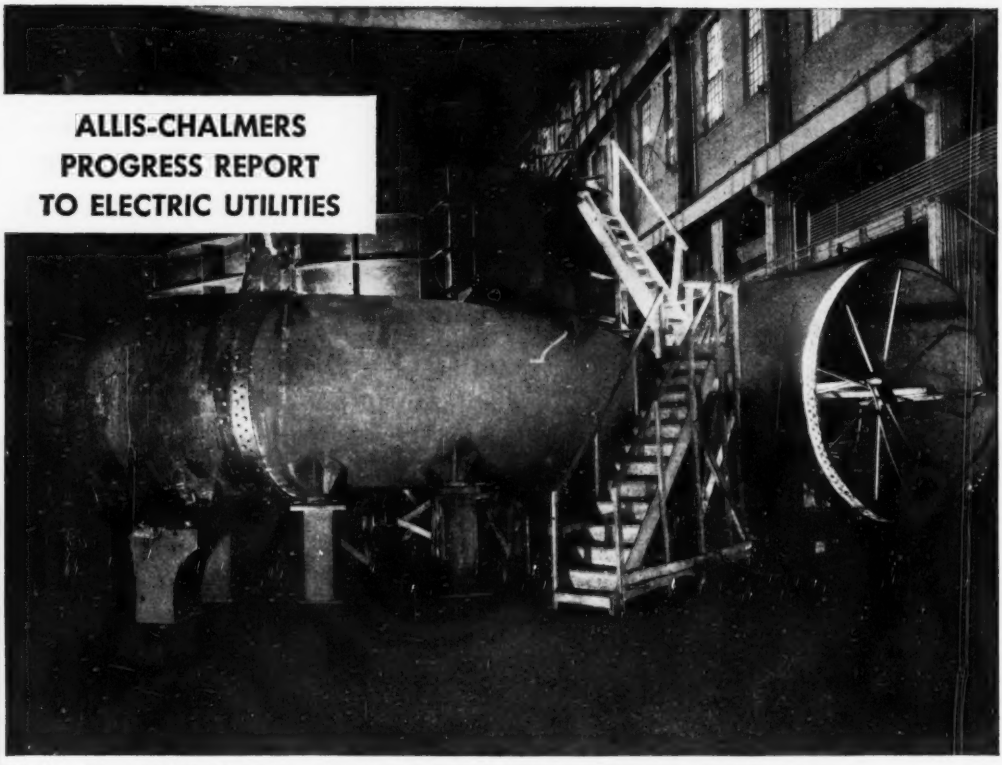

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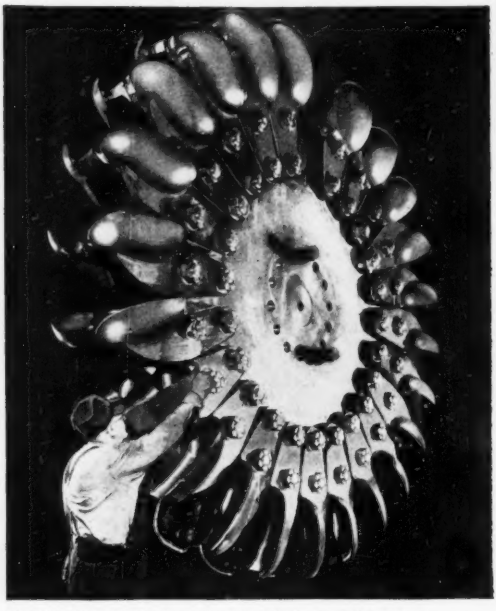
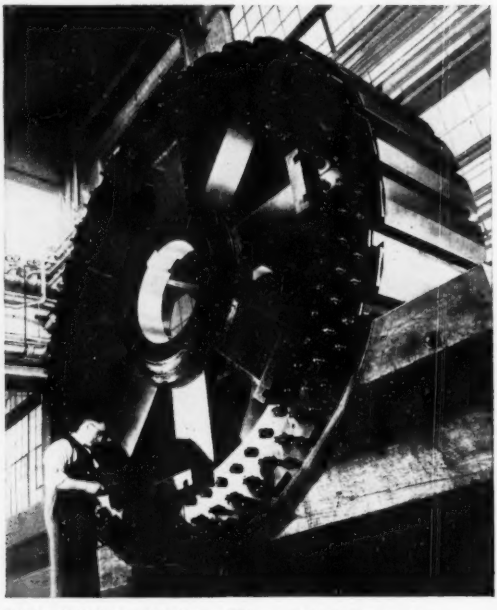


NEW BUCKET DESIGN on wheel for 56,000 hp, 2,200 ft head



ROTOR SPIDER for 33,000 kva, 225 rpm, horizontal generator

A-C Production Keeps Pace with Hydro-Power Expansion

EACH RISE IN COAL PRICES enhances the value of existing hydro-electric plants and makes the development of additional waterpower sources all the more desirable.

J. F. Roberts
Mgr., Hydraulic

Today, with over 11,000,000 hp of A-C hydraulic turbine equipment of all principal types — impulse, Francis and propeller — installed throughout the world at such famous sites as Hoover, Shasta, Pickwick Landing, Shipshaw, and Niagara, Allis-Chalmers production continues to keep pace with new expansion.

Among important orders in work are a third 91,800 hp, 2231' head impulse turbine for the Brazilian Traction Company; two more 115,000 hp, 480' hd. Francis units for Hoover Dam; four 105,000 hp, 400' hd. for Hungry Horse; one 82,500 hp, 280' hd. for City of Seattle; a 45,000 hp, 188' hd. for Carolina Aluminum; four 57,500 hp, 112' hd. units for Fort Randall; a fourth unit, 29,000 hp, 70' hd., for Alabama Power Co. Mitchell Dam; four large cabinet type governors for McNary Dam units and four for Clark Hill.

In addition to new turbine units, A-C has contributed to the modernization and rebuilding of many existing turbines . . . increasing capacities, efficiencies and service span.

New buckets, among the largest A-C has built, of improved all-welded construction for 60 cycle operation have now replaced older types of buckets at the Big Creek 2A and Kern River plants of South. California Edison Co.

Another hydro-plant on the Ohio River increased output almost 15% with new propeller type replacement runners designed to give increased capacity under reduced head conditions.

And to obtain still greater power from four 24,000 hp, 180' head units, 25 years old, the Carolina Aluminum Company recently installed four new runners of 31,000 hp capacity under 188' head.

GENERATORS. Hydraulic Turbine Generators shipped during the year included three 33,000 kva horizontal units, among largest of this type, for a West Coast installation.

R. S. Fleshiem
Mgr., Electrical

Also shipped was the second pair of 35,500 kva units for Fort Loudon. Both a 38,889 kva and 16,667 kva generator are already installed in the Fort Peck Project on the Missouri, and a second 38,889 kva unit is under construction. Two 82,500 kva generators are now being built for Hoover Dam.

Other large units in production include three 42,100 kva, one 37,500 kva, four 12,500 kva, five 16,669 kva, and two 18,000 kva generators.

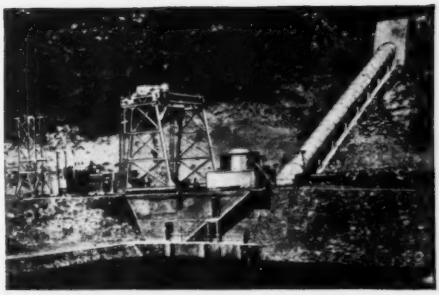
Indicative of the wider use of outdoor machines are A-C units installed at Upper and Lower Malad hydro-plants, and the 17,500 kva units being installed at Lower Salmon.

★ ★ ★

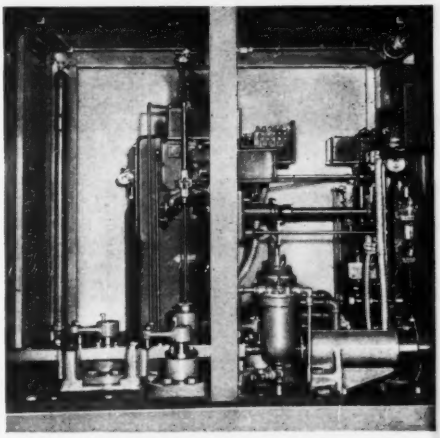
Building not only all principal types of hydraulic turbines, but the generators, power transformers and switchgear as well, Allis-Chalmers is the only company with centralized facilities for coordinating both hydraulic and electrical equipment.

It's just one good reason why more hydraulic power project engineers throughout the world are looking with confidence to Allis-Chalmers as a source of equipment supply. ALLIS-CHALMERS, 932A S. 70 ST., MILWAUKEE 1, WIS.

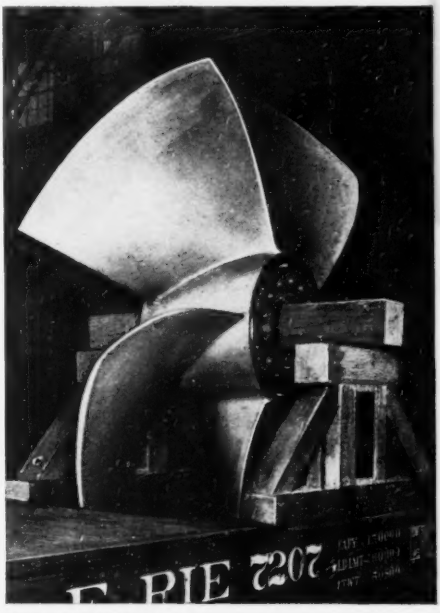
A2714



OUTDOOR hydro-generator trend, 8400 kva, 12000 hp



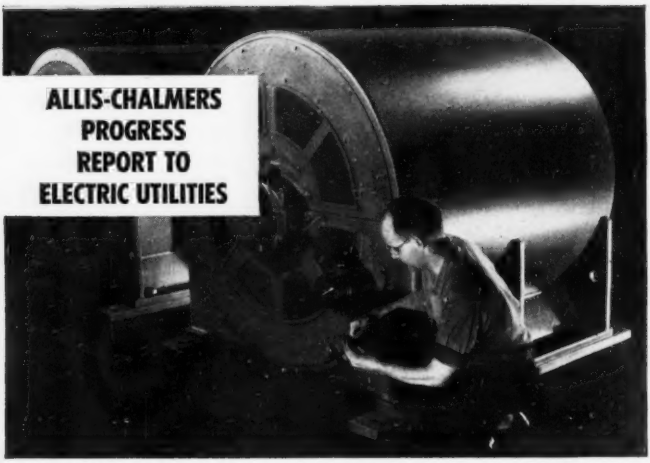
CABINET-TYPE GOVERNOR with super-sensitive mechanism



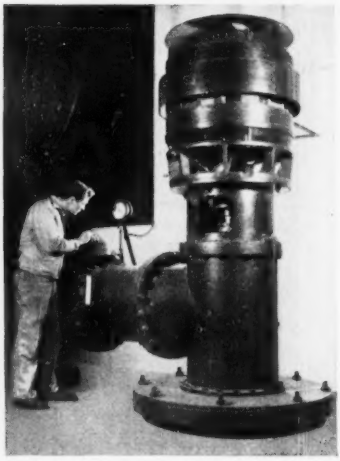
OUTPUT INCREASED 15% with replacement propeller runner

ALLIS-CHALMERS

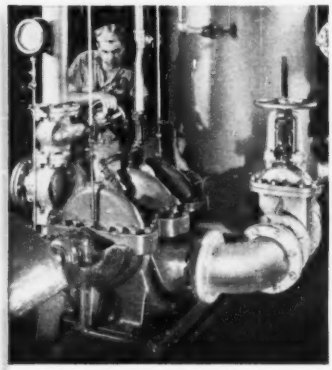
Pioneers in Power and Electrical Equipment—Builders of the World's Widest Range of Major Industrial Equipment!



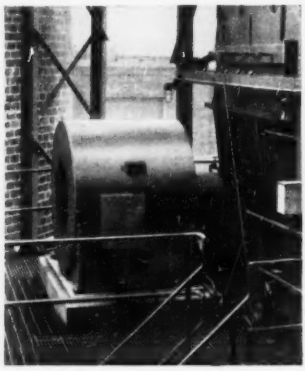
PRACTICALLY SELF-CLEANING 500 hp tube-type TEFC motors for draft fan drives



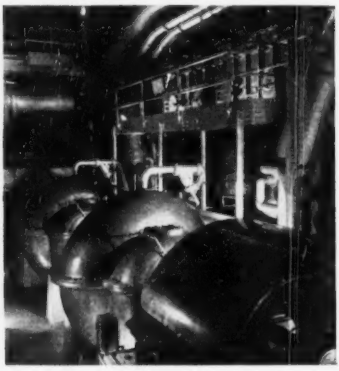
VERTICAL MIXED-FLOW, 38 x 24, 11800 gpm



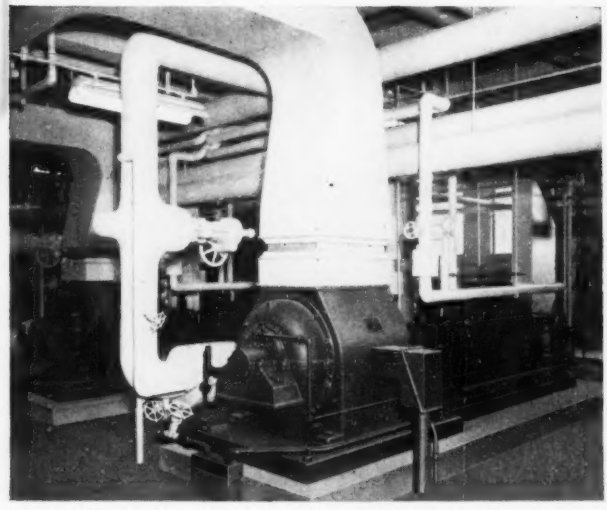
8 x 6 CONDENSATE pump, 500 gpm, 159' hd



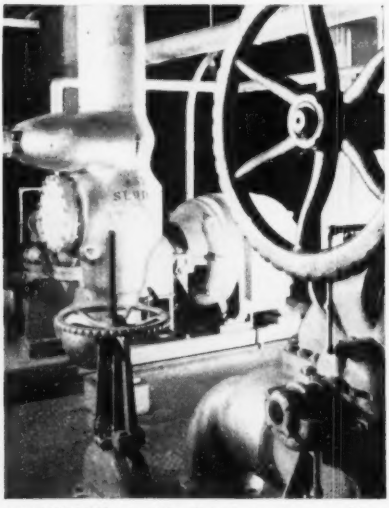
300 HP tube-type TEFC fan drive



54 x 48 CIRCULATING water pumps, drives



RELIABLE 2-POLE, 1000 hp Cage Motors driving 7-stage Boiler Feed Pumps



ASH SLUICING—two 10 x 8 single-stage pumps, drives

Lines Expanded, Deliveries Stepped-up on Allis-Chalmers Power House Auxiliaries

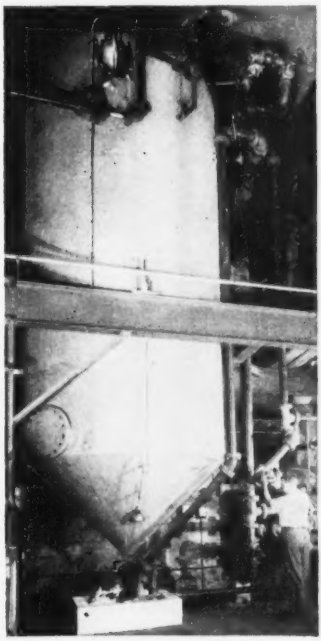
CENTRIFUGAL PUMPS. Improvement and expansion of facilities, including near-completion of one of the most advanced pump test set-ups in the industry, plus many detail improvements have been made in A-C's line of power plant pumps during the past year.

H. P. Binder
Mgr. Cent. Pump

The addition of several new pumps rounds out the line of Boiler Feed, Circulating, Condensate Removal, Heater Drain, Service Water, Wash Water, Feedwater Treatment, Evaporator Feed, Boiler Recirculating and Ash Sluicing pumps.

Shipment on doubleton and other large multi-stage pumps has been reduced to under a year. And smaller standard lines are being delivered in 15 to 40 days.

Demand for mixed flow pumps for condenser circulating water service is increasing. A new impeller design, in this line, provides better efficiency and suction head characteristics, and a new discharge elbow also contributes to increased efficiency.



6000 GHP A-C hot process softener

Manufacture has begun on the first of a new line of high-pressure, barrel-type boiler feed pumps. The design offers high efficiencies made possible by exhaustive research employing the wind-tunnel technique. Typical of many boiler feed pumps built in the past year were three 6" x 5", seven stage pumps with stainless steel casings —third group of repeat orders by one customer.

Hydraulic systems for handling fly-ash are growing steadily. Applications of the type CW Allisite metal solids pumps for ash slurries indicate that this pump is extremely satisfactory for this service.

★ ★ ★

WATER CONDITIONING. Combining wide experience in design and application of power generation equipment with a complete 3-way program of service, chemicals and equipment, Allis-Chalmers is steadily increasing its Water Conditioning clientele. Utility as well as industrial. Experience in conditioning boiler water in thousands of high and low pressure plants qualifies A-C to assist in selection of both process and equipment requirements.

Service includes complete analysis of water supplies; reports on water-steam cycle; study of present equipment; advice on selection of chemicals; periodic reports and service calls.

Chemicals—Scale inhibitors for all heat exchange cycles. Special chemicals to prevent boiler scale, control corrosion, reduce silica, and correctly condition sludge.

T. J. Hodan, Mgr.,
Water Conditioning

Equipment—Hot and cold process softeners; sodium and hydrogen zeolite softeners; degasifiers; deionizers; chemical proportioners; oil removal and water filters.

Typical of large equipment orders for Utilities is the installation of hot process lime soda unit and hot phosphate softeners which will treat 300,000 lbs. water per hour for a western Utility.

AUXILIARY MOTORS. An outstanding recent development is the tube-type totally-enclosed fan-cooled motor which, because of its suitability for outdoor operation, can often do much to counteract high power plant construction costs. Proved by three years of successful operation under severe conditions—indoors and out—in all latitudes—tube-type motors are now offered in sizes from 75 to several thousand horsepower.

Available in squirrel cage, wound rotor, and synchronous designs—in both horizontal and vertical types, tube-type TEFC motors are being specified for more and more draft fan and pump drives. Designed to provide full internal air circulation for uniform cooling, these motors offer many practical advantages such as: Maintenance reduced to a point never before possible; practically self-cleaning straight-tube air-to-air heat exchanger; all electrical parts—including the stator core — enclosed against outside air.

R. M. Casper, Mgr.,
Motor & Generator

Continued engineering and development work is further strengthening Allis-Chalmers' position of leadership in the high-speed boiler feed pump motor field. Such features as "tear-drop" rotor bars silver-brazed into the end rings, non-embrittling copper alloy end rings, separate steel balancing rings, liberally designed bearings, deep-set stator coils for increased air gap air flow, and careful attention to air passages to minimize windage noises . . . all these and many more are typical of the advanced design thinking behind the reliability of Allis-Chalmers two-pole cage motors.

This reliability of operation and the resulting growing preference for Allis-Chalmers motors have brought orders and production to record levels. Typical are the five 3500-hp, two-pole cage motors for boiler feed pumps, which will be the largest of their type built for any service.

Large or small Allis-Chalmers motors are available for all power plant requirements. Now with improved deliveries, you can obtain the kind of performance that has built up A-C's reputation for reliable power house motors.

★ ★ ★

More than 60 years of pump building —65 years in electric power equipment stand behind the "A-C" trademark. For power plant auxiliaries, power generation, distribution, control or utilization equipment, an Allis-Chalmers representative is a good man to call! ALLIS-CHALMERS, 932A SOUTH 70TH STREET, MILWAUKEE 1, WIS.

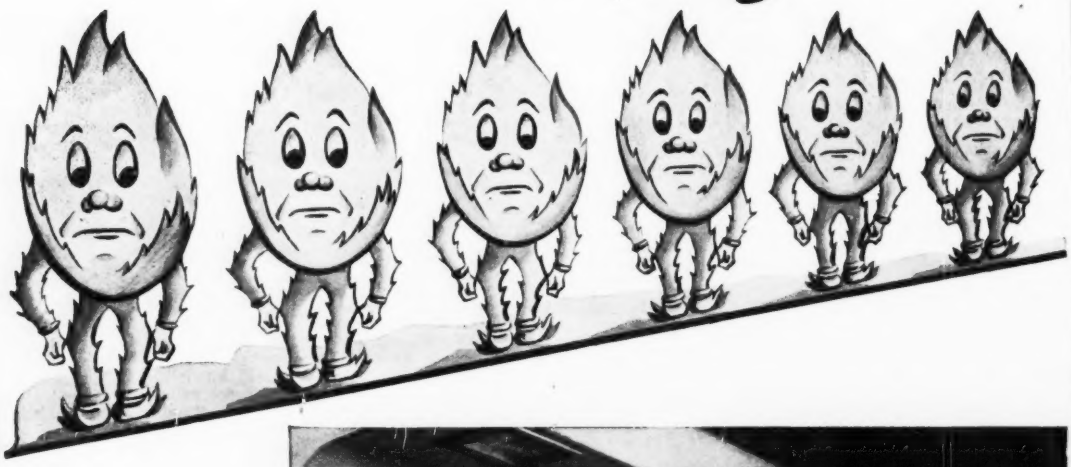
A2715

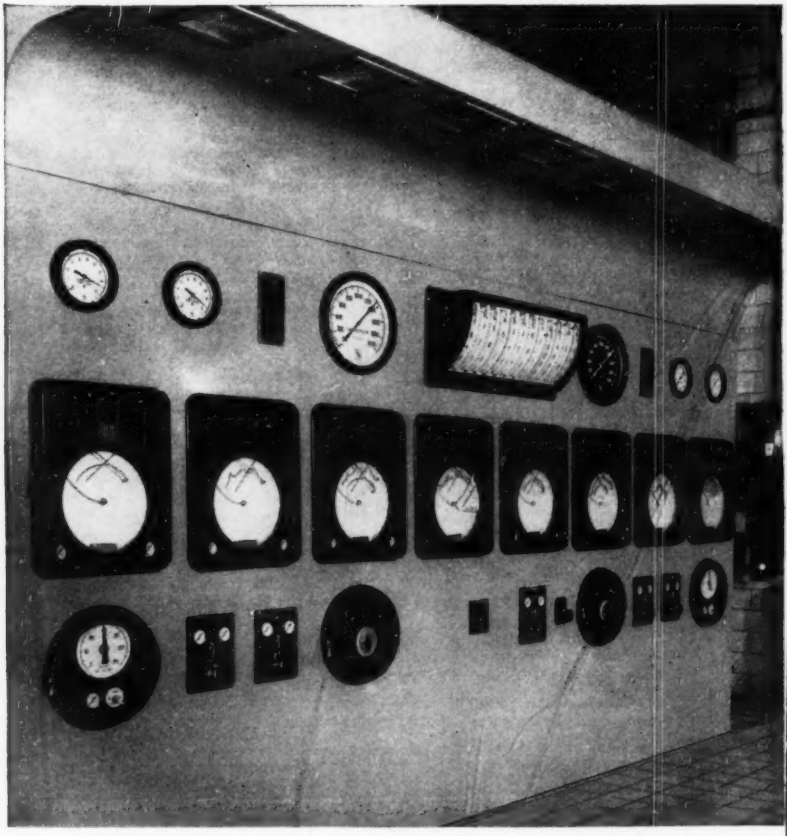
Allisite is an Allis-Chalmers Trademark

ALLIS-CHALMERS

Pioneers in Electric Power & Major Industrial Equipment!

Keeping Btu's



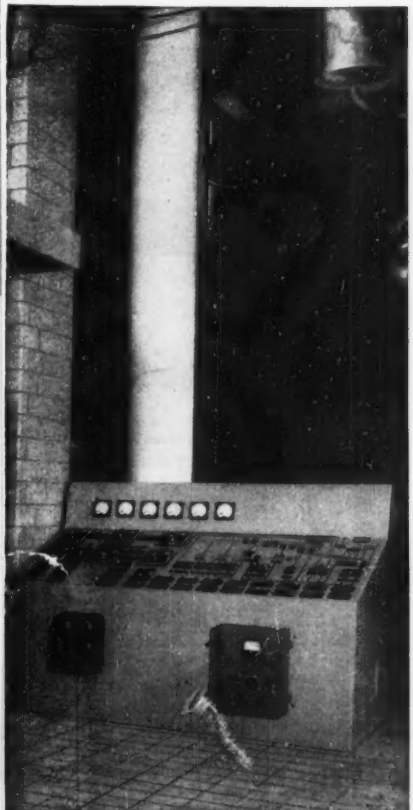


Bailey Boiler Control Panels for 200,000 lb per hour capacity, 880 psi, 900° F pulverized coal-fired boiler at the Hudson Steam Plant of Rockland Light and Power Company, Tomkins Cove, New York. All

Branches in: Atlanta, Boston, Buffalo, Charlotte, Chicago, Cincinnati, Denver, Detroit, Houston, Kansas City, Los Angeles,

IN LINE

at Tomkins Cove



Boiler Controls are co-ordinated to insure efficient handling of the heat energy released in combustion.

● Optimum conditions in routine operation are provided for at the Hudson Steam Plant of Rockland Light and Power Company. This new station at Tomkins Cove, New York, keeps Btu's in line with a complete installation of Bailey Boiler Controls, all co-ordinated to work as a team in directing the efficient use of heat energy.

The installation includes:

Bailey Combustion Control

Bailey Three-element Feed Water Control

Bailey Steam Temperature Control

Bailey Coal-Air Temperature Control

Bailey Three-element Condensate Control.

It's easy to keep Btu's in line with co-ordinated controls engineered to fit your plant.

Call your local Bailey Engineer for recommendations on how meters and controls can help you to get more useable heat energy from your fuels.

A-108-2

BAILEY METER COMPANY

1060 IVANHOE ROAD · CLEVELAND 10, OHIO

BAILEY METER COMPANY LIMITED, MONTREAL, CANADA

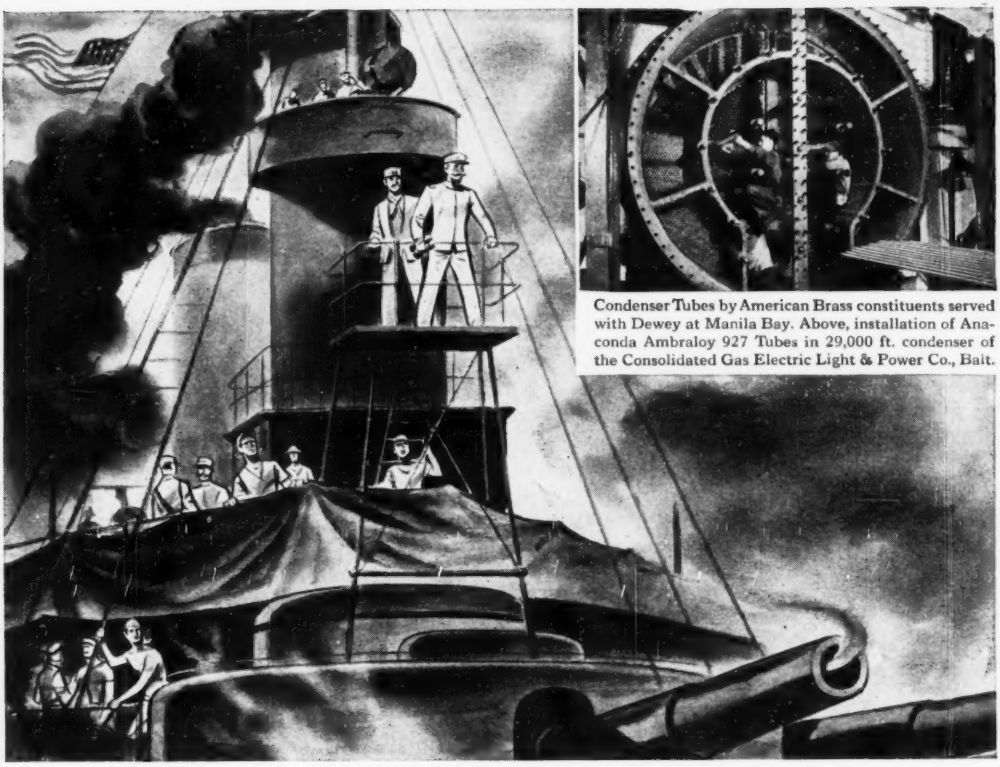
BAILEY METERS

Controls for Steam Plants

COMBUSTION · FEED WATER · TEMPERATURE

PRESSURE · LIQUID LEVEL · FEED PUMPS

Milwaukee, New Orleans, New York, Philadelphia, Pittsburgh, St. Louis, St. Paul, San Francisco, Schenectady, Seattle.



Condenser Tubes by American Brass constituents served with Dewey at Manila Bay. Above, installation of Anaconda Ambraloy 927 Tubes in 29,000 ft. condenser of the Consolidated Gas Electric Light & Power Co., Balt.

The U.S. History of Condenser Tubes is a Story of AMERICAN BRASS

FOR MORE THAN TWENTY YEARS before the steam turbine brought surface condensers into the electrical generating scene, founding members of The American Brass Company had been furnishing seamless, cold-drawn copper and copper alloy condenser tubes to American naval and merchant ships and to the British Admiralty.

Manufacture of these tubes was first begun by the cast shell method in 1870. Since then, members of The American Brass family have taken the lead in condenser tube development.

In the 90's Benedict Metal provided the first cupro-nickel tubes.

In 1896—importation of the Mannesmann Process for hot rolling tubes.

In the late 90's—the first Admiralty tubes.

In 1909—the cup-drawn process for tubes.

In 1912—the finishing light anneal to eliminate the tendency to lengthwise splitting known as "season cracking."

In 1930—the first use of extrusion presses for condenser tube stock; which, after cold rolling and drawing still produces the most physically perfect tubes.

New 40-page booklet on Condenser Tubes and Tube Sheets, currently produced in eight standard and several special alloys, now available. Write for Publication B-2.

ANACONDA
from mine to consumer

Anaconda

CONDENSER TUBES

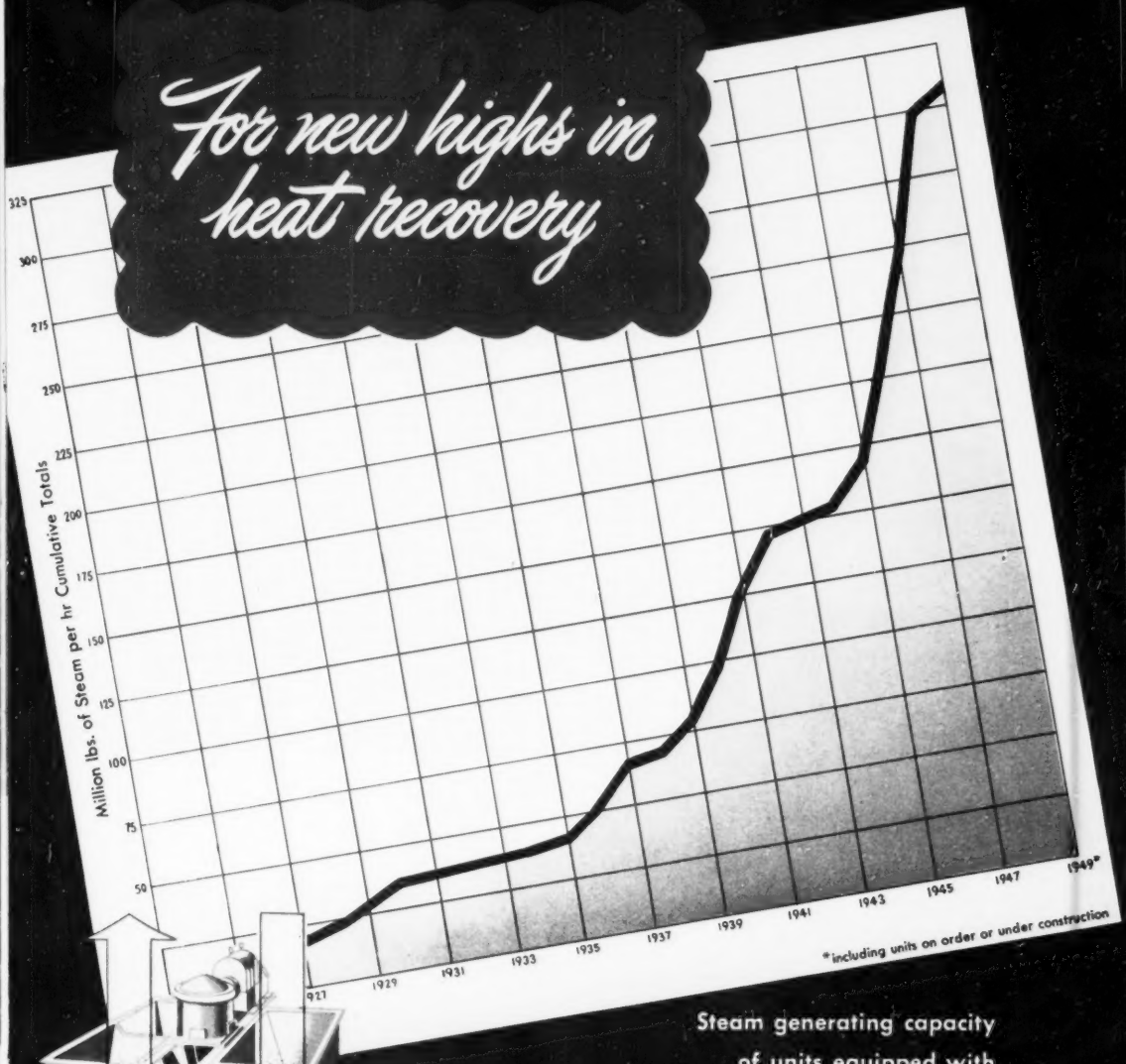
THE AMERICAN BRASS COMPANY

General Offices: Waterbury 88, Connecticut

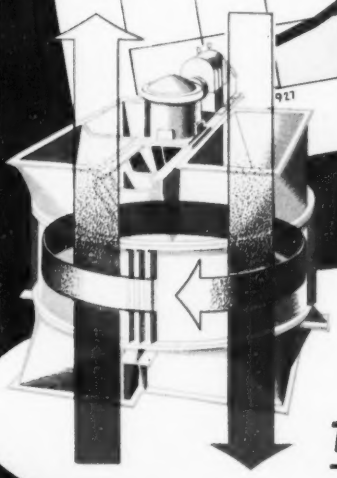
Subsidiary of Anaconda Copper Mining Company

In Canada: ANACONDA AMERICAN BRASS LTD., *New Toronto, Ont.*

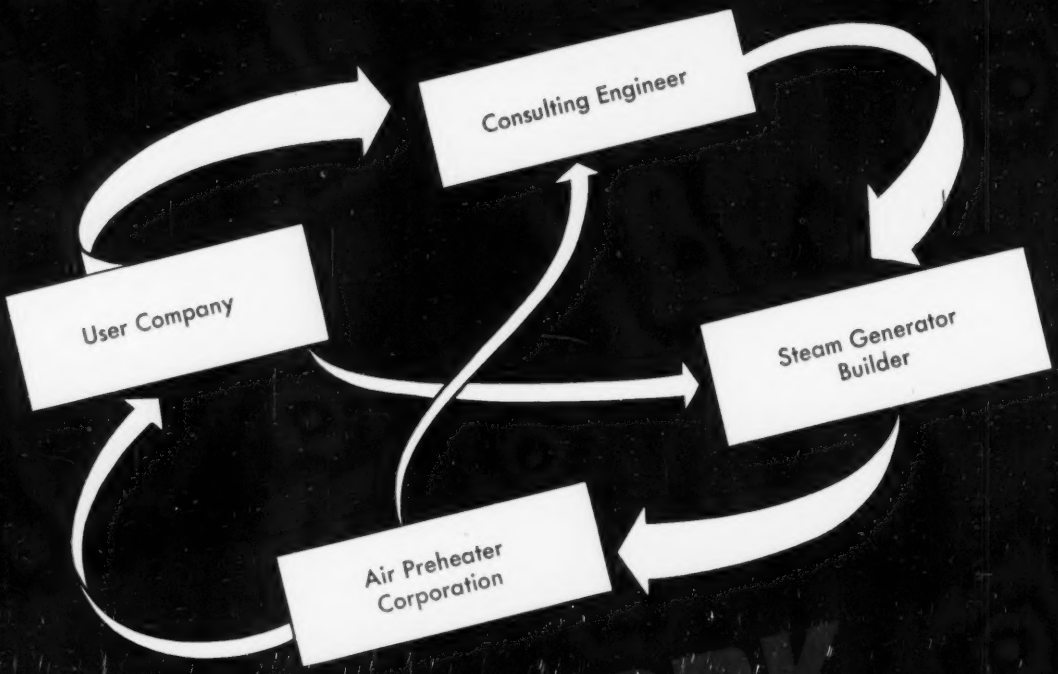
For new highs in heat recovery



Steam generating capacity
of units equipped with
Ljungstrom Air Preheaters



The AIR PREHEATER CORPORATION



26 Years of

TEAMWORK

raises the efficiency of steam generation

Behind every well integrated steam generating plant — matched to the operating requirements of the user—is a team of co-operating minds. All have a single objective — the overall economic balance of the plant.

Air Preheater engineers work hand in hand with all the builders of steam generators to assure you an integrated design. For the consulting engineers and the engineering and operating staffs of user-companies, we stand ready with engineering data and operating guidance. This association with others responsible for the great strides made in steam generation is a source of pride, and an added stimulus to our own product improvement and planning.

The number of "repeat users" of Ljungstrom air preheaters — at more and more efficient plants—is a measure of achievement made possible by this close-knit teamwork.

The AIR PREHEATER CORPORATION

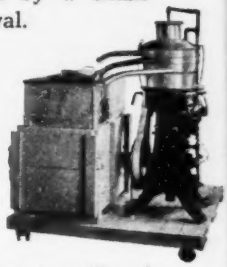
60 East 42nd Street, New York 17, New York

SINCE 1878 ... DE LAVAL MACHINES HAVE BEEN FIRST

1878 - Carl Gustav De Laval invents the first continuous centrifugal Cream Separator. Tries tubular bowl design.

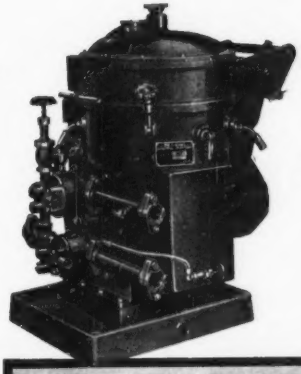
1879 - Dr. De Laval abandons tubular type bowl for the more efficient wide disc bowl revolving at lower rpm.

1918 - First centrifugal Oil Purifier introduced by De Laval. This continuous Oil Purifier was driven by a small steam turbine, also invented by Dr. De Laval.



1922 - First De Laval centrifugal Insulating Oil Purifier installed. In 1949, the De Laval method is still the safest way to maintain insulating oil because water, once discharged, cannot recontaminate the dehydrated oil.

1934 - De Laval introduces the "Uni-Matic," first centrifugal Oil Purifier available with integral pumps and heater.



1949 - New, larger Model 67 "Uni-Matic" with purifying capacity of approximately 450 gph on turbine oil. De Laval, backed by 71 years of experience with centrifugal purification, continues to provide power plants with the means of utilizing centrifugal force most effectively and economically.

THE DE LAVAL SEPARATOR COMPANY
165 Broadway, New York 6 427 Randolph St., Chicago 6
DE LAVAL PACIFIC CO., 61 Beale St., San Francisco 5
THE DE LAVAL COMPANY, Limited, Peterborough, Ont.

DE LAVAL OIL PURIFIERS

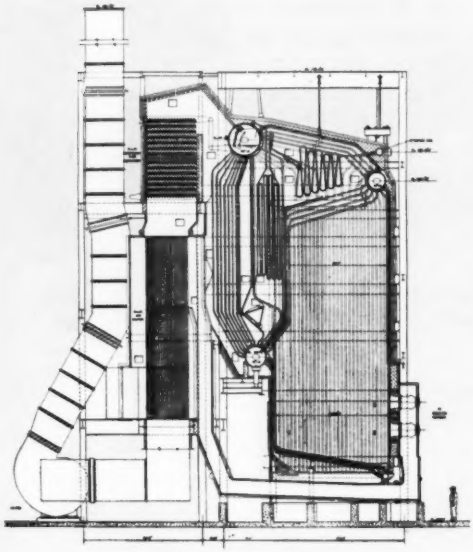
for more dependable power production

All of these Public Utilities have recently ordered Riley Steam Generating Units

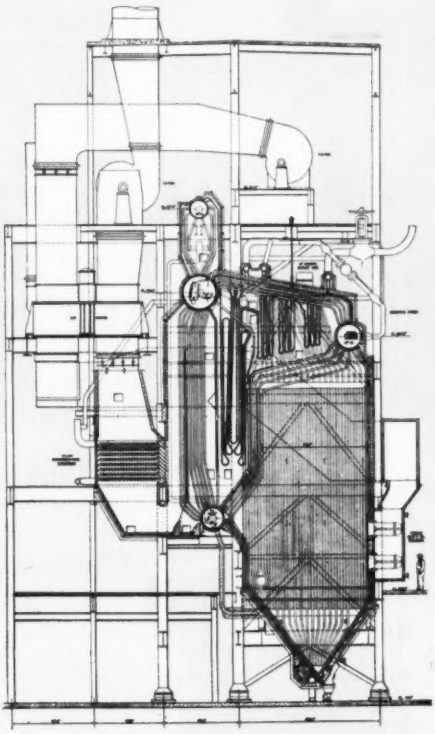
- Houston Lighting & Power Co.
- Public Service Co. of Indiana
- Arkansas Power & Light Co.
- New England Power Association
- Northern Virginia Power Co.
- Utah Power & Light Co.
- Central Illinois Light Co.
- Carolina Power & Light Co.
- Union Electric Co. of Mo. & Ill.
- Southwestern Public Service Co.
- New Orleans Public Service Co.
- Interstate Power Co.
- Otter Tail Power Co.
- Central Ohio Light & Power Co.
- Lynn Gas & Electric Co.
- Northwestern Public Service Co.
- Southern Ind. Gas & Electric Co.
- Pennsylvania Edison Co.
- Iowa-Illinois Gas & Electric Co.
- West Penn Power Co.
- Ohio Edison Co.
- South Carolina Power Co.
- Mississippi Power Co.
- Gulf Power Co.
- Upper Mich. Power & Light Co.
- North Dakota Power & Light Co.

The SWING in the

There is a very noticeable swing among Public Utilities to Riley Steam Generating Equipment. More and more Public Utility Companies are making their initial installation of Riley equipment and those companies who have tried Riley equipment are, almost invariably, coming back for more Riley units when expanding capacity. More than 70% of Riley's total sales during the past few years has been to public utility companies. Riley has installed or on order over 30,000,000 lbs. of steam capacity in public utility plants.



HOUSTON LIGHTING & POWER CO., Houston, Texas
850,000 lbs./hr. 1025 lbs. 905°F.
Houston Lighting & Power Company has installed or on order 9 Riley Units
4,590,000 lbs./hr. capacity of Riley Units



CITY OF LOS ANGELES—HARBOR STEAM STATION
825,000 lbs./hr. 1200 lbs. 900°F.
There are five Riley Steam Generating Units in this Plant
3,825,000 lbs./hr. capacity of Riley Units

TRADE MARK Rx REGISTERED

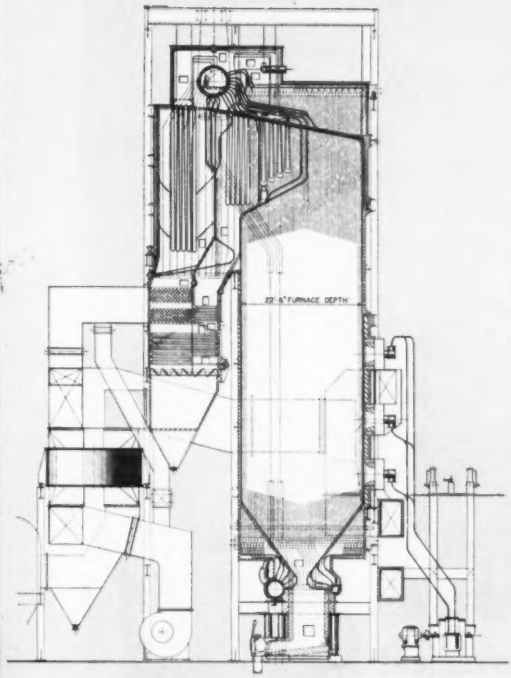
RILEY

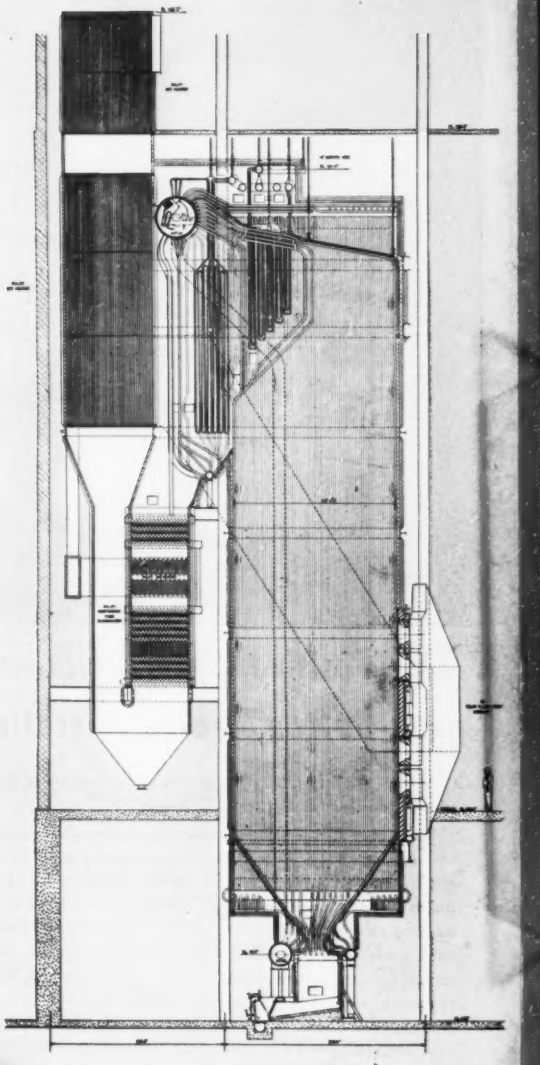
STOKER CORPORATION, WORCESTER, MASS.

Boston · New York · Philadelphia · Washington · Buffalo · Pittsburgh · Cleveland · Detroit · Chicago
Cincinnati · Atlanta · New Orleans · Memphis · St. Louis · Kansas City · St. Paul · Tulsa · Houston
Denver · Salt Lake City · Los Angeles · Portland · Seattle

BOILERS • PULVERIZERS • BURNERS • STOKERS • SUPERHEATERS • FLUE GAS SCRUBBERS

Central Station field is to RILEY





UTAH POWER AND LIGHT CO., Salt Lake City

620,000 lbs./hr. 1500 lbs. 955°F.
Utah Power and Light Co. is also installing
a 450,000 lbs./hr. 1050 lbs. 905°F. Riley
Steam Generating Unit fired by Riley
Pulverizers in one of their other plants
1,070,000 lbs./hr. capacity of Riley Units

CENTRAL ILLINOIS LIGHT CO., Peoria, Ill.

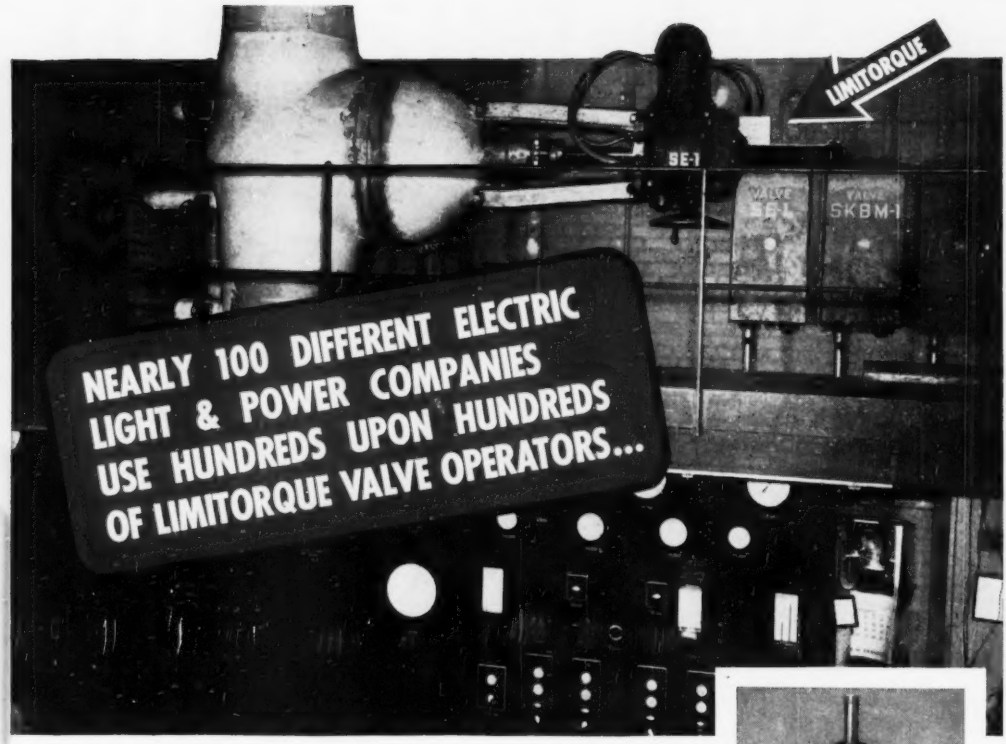
600,000 lbs./hr. 950 lbs. 900°F.
There are four additional Riley
Steam Generating Units in this plant
1,875,000 lbs./hr. capacity of Riley Units

A survey of your Power Plant by a consulting engineer will possibly show ways of making surprisingly large savings in [illegible] costs

COMPLETE STEAM GENERATING UNITS

. . . it will pay you to visit modern Riley Installations before purchasing Boiler or Fuel Burning Equipment

ECONOMIZERS • WATER-COOLED FURNACES • STEEL-CLAD INSULATED SETTINGS • AIR HEATERS


LIMITORQUE
SE-1
VALVE
SKBM-1
NEARLY 100 DIFFERENT ELECTRIC LIGHT & POWER COMPANIES USE HUNDREDS UPON HUNDREDS OF LIMITORQUE VALVE OPERATORS...

...for Positive, Safe, Quick and Convenient "*push-button*" valve operation...

In fact, the list of Central Stations using *LimiTorque* reads like a "Who's Who" of the industry.

LimiTorque is a sensitive, automatic, mechanically actuated device for opening and closing globe, gate, butterfly and rotary plug valves; sluice gates; factory and hangar doors; induced and forced damper controls; sprinkler systems; feeder dis-connect switches, etc. Most valves are damaged by improper seating, or by meeting some obstruction in closing . . . *LimiTorque* control gives absolute assurance against improper seating, by means of a positive safety overload mechanical torque cut-out. If obstruction is met in closing valve, the torque switch becomes operative, and dis-connects the motive power—thus preventing broken gates or discs and damaged stems. *LimiTorque* is the only automatic valve operating device that employs this positive principle of operation and control.

THE TYPE "S" LIMITORQUE

Send for the 96-page Catalog, and please use your Business Letterhead when writing.

Philadelphia Gear Works, INC.

ERIE AVE. AND G ST., PHILADELPHIA 34, PA.
NEW YORK • PITTSBURGH • CHICAGO
IN CANADA: WILLIAM AND J. G. GREEY LIMITED, TORONTO

Industrial Gears and Speed Reducers
LimiTorque Valve Controls

FIGURES

that tell the story of a quarter century of progress in Power Generation

1923

2.4 lb/Kw-hr

36,088,000,000 Kw-hr generated from fuel.
43,306,000 tons — coal and coal equivalent of oil and gas.

1948

1.3 lb/Kw-hr

197,215,000,000 Kw-hr generated from fuel.
128,000,000 tons — coal and coal equivalent of oil and gas.

Had 1948 output been produced at 1923 fuel rate, fuel consumption would have been 236,658,000 tons—or almost twice as much as was actually used.

Thus technological progress over the past quarter century has enabled the electric utility industry to make a vast contribution toward conservation of fuel, our most valuable natural resource, while effecting an annual economy — in fuel costs alone (assumed average cost of $6.50 per ton) — of more than

$700,000,000.

This saving has been a major factor in enabling the industry to occupy the unique position of selling its product today at an average rate that is still below the pre-war price.

C-E

COMBUSTION ENGINEERING—SUPERHEATER, INC.

200 Madison Avenue · New York 16, N. Y.

Among the major advances in steam generating practice which have contributed to this progress are the . . .

. . . FOLLOWING

ADVANCES

in steam generation that have contributed importantly to power progress during the past quarter century

PULVERIZED COAL FIRING

The first utility station designed for pulverized coal firing was built in 1920 and by 1923 the trend to this method of firing large boilers was firmly established.

WATER COOLED FURNACES

Beginning with the bottom water screen in 1920, the extension of water cooling to rear, side and front walls was accepted practice by the middle twenties.

Port Washington Station, Wisconsin Electric Power Company

Established efficiency standard for modern power station performance. Three C-E Steam Generating Units in service, a fourth being installed and a fifth on order.

East River Station, Consolidated Edison Co. of New York

First power station to install boilers capable of producing 1,000,000 lb of steam per hr — three C-E Steam Generating Units.

Sewaren Station, Public Service Electric & Gas Company

First power station to generate steam at temperature above 1000 F. Two C-E Steam Generating Units in service, a third being installed and a fourth on order.

Lakeside Station, Wisconsin Electric Power Company

First utility power station to be designed for pulverized coal firing. Equipped with C-E Pulverized Coal System.

The leading manufacturers of steam generating equipment have all had a share in bringing about these and other advances which have contributed so greatly to the remarkable progress achieved in power generation during the past quarter century. But the credit must also be shared with the engineers of the Utility Companies who not only gave every possible aid to progressive ideas, but who also in many instances courageously permitted the use of their stations

IMPROVED SUPERHEAT CONTROL

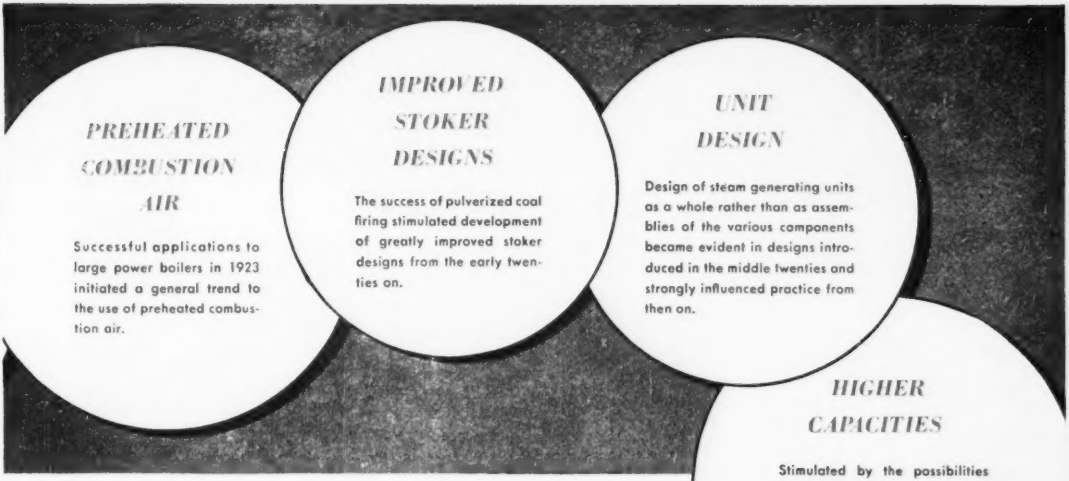
Various methods and combinations of methods were developed in the late thirties to solve the difficult problem of superheat control over a wide range of steam output. The most satisfactory answer to date is vertically adjustable firing, developed in the early forties.

IMPROVED AUXILIARIES

Designs of auxiliaries—instruments and controls, fans, pumps, drives, etc.—have kept pace with the general advancement of steam generating practice and have contributed importantly to improved operation and reliability.

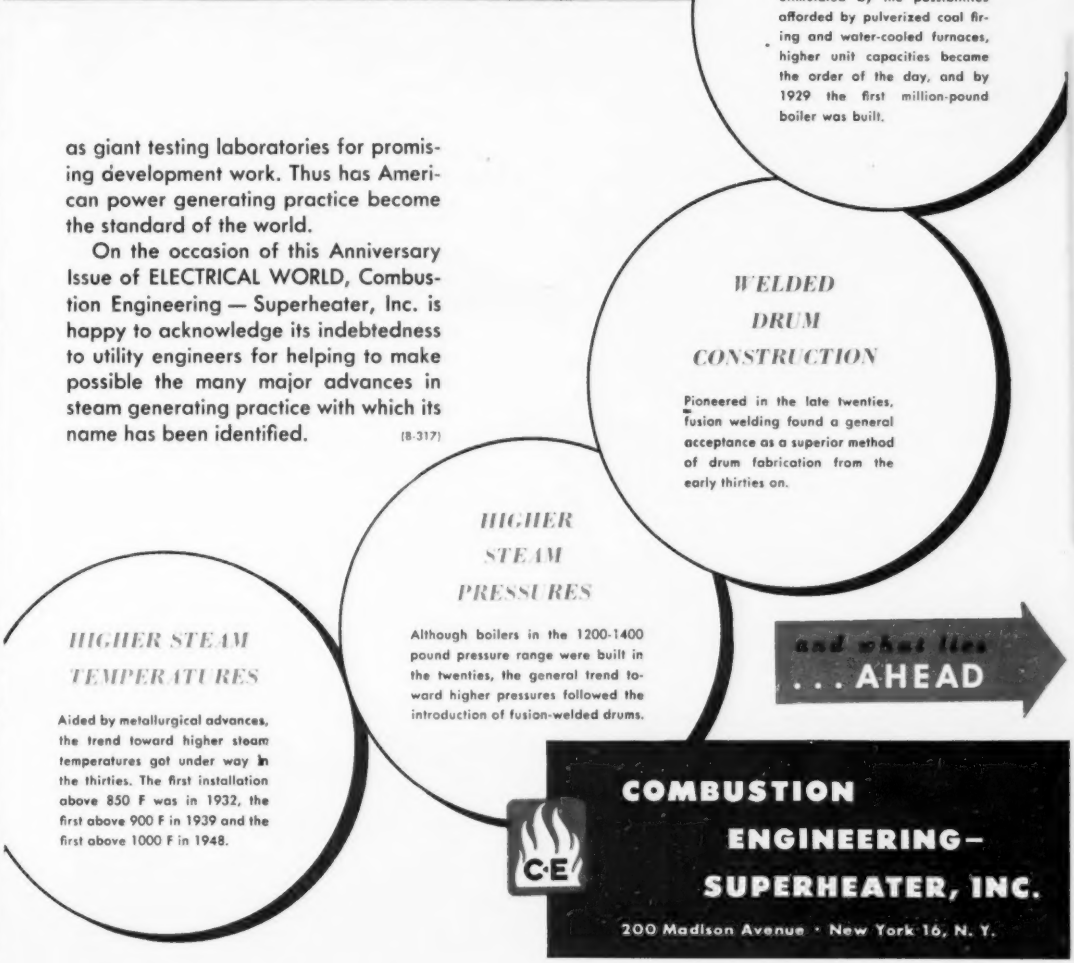
IMPROVED AVAILABILITY

The first large single boiler-turbine installation was completed in 1935. The recognition of boiler availability as being on a par with turbine availability grew steadily and has been generally accepted for some years.


PREHEATED COMBUSTION AIR
Successful applications to large power boilers in 1923 initiated a general trend to the use of preheated combustion air.
IMPROVED STOKER DESIGNS
The success of pulverized coal firing stimulated development of greatly improved stoker designs from the early twenties on.
UNIT DESIGN
Design of steam generating units as a whole rather than as assemblies of the various components became evident in designs introduced in the middle twenties and strongly influenced practice from then on.
HIGHER CAPACITIES
Stimulated by the possibilities afforded by pulverized coal firing and water-cooled furnaces, higher unit capacities became the order of the day, and by 1929 the first million-pound boiler was built.

as giant testing laboratories for promising development work. Thus has American power generating practice become the standard of the world.

On the occasion of this Anniversary Issue of ELECTRICAL WORLD, Combustion Engineering — Superheater, Inc. is happy to acknowledge its indebtedness to utility engineers for helping to make possible the many major advances in steam generating practice with which its name has been identified. (B-317)


WELDED DRUM CONSTRUCTION
Pioneered in the late twenties, fusion welding found a general acceptance as a superior method of drum fabrication from the early thirties on.
HIGHER STEAM PRESSURES
Although boilers in the 1200-1400 pound pressure range were built in the twenties, the general trend toward higher pressures followed the introduction of fusion-welded drums.
HIGHER STEAM TEMPERATURES
Aided by metallurgical advances, the trend toward higher steam temperatures got under way in the thirties. The first installation above 850 F was in 1932, the first above 900 F in 1939 and the first above 1000 F in 1948.
and what lies . . . AHEAD

COMBUSTION ENGINEERING—SUPERHEATER, INC.

200 Madison Avenue · New York 16, N. Y.

Fuel rates will go lower as new power goes on the line . . . thanks to modern design

Present day designs of steam generating units reflect important post-war advances. Particularly notable progress has been made in developing designs for the simplified reheat cycle now being so widely adopted. Other advances are reflected in the overall simplicity and compactness of today's units and in design features which assure high availability with low-grade coals; ability to use coal, oil or gas as desired; the maintenance of constant steam temperature over a wide range of output; and improved steam purification and automatic control.

Most of the capacity now becoming operative will produce kw-hrs at a fuel rate of less than one pound. Sufficient of this capacity will be in service by the end of this year to result in a resumption of the downward trend of the fuel rate. As the proportion of new capacity to old increases, this trend will accelerate.

New Power for America
Lights will not go out in America, nor will progress stand still for lack of power, if the nation's electric utilities can help it. And they began to plan this help a decade ago through an expansion program — interrupted by the war — that is now well on the way to being realized.
In 1947 privately owned utilities expanded over 60 per cent more for new steam power capacity than in the previous all-time peak year (1930). 1948 expenditures were nearly double 1947 and 1948 will substantially exceed 1948.
In the four-year period, 1948 through 1951, the total capital expenditures by private utilities for expansion of electric service to the homes and industries of America will have exceeded ... billion dollars.
It is equally significant that, in a time of skyrocketing costs, the electric utilities have regularly served the last stand of their product at a level maintaining the price of the 100-cent dollar.
So there should be little wonder, except a moment, that current conditions in public utility rates — and early — increase in public utility light and power will continue to be America's fare for a day.
This unique situation is due in large measure to technological improvements during the last quarter century — improvements to which Combustion Engineering made early important contributions as the pioneering of pulverized coal firing, water-cooled furnaces, and new and better designs of steam generating equipment and methods of firing. This experience in developing steam power stations is reflected in the extensive C-E line available for all users of steam.
Combustion Engineering—Superheater, Inc.
200 MADISON AVENUE • NEW YORK 16, N. Y.
C-E

A story that should be told

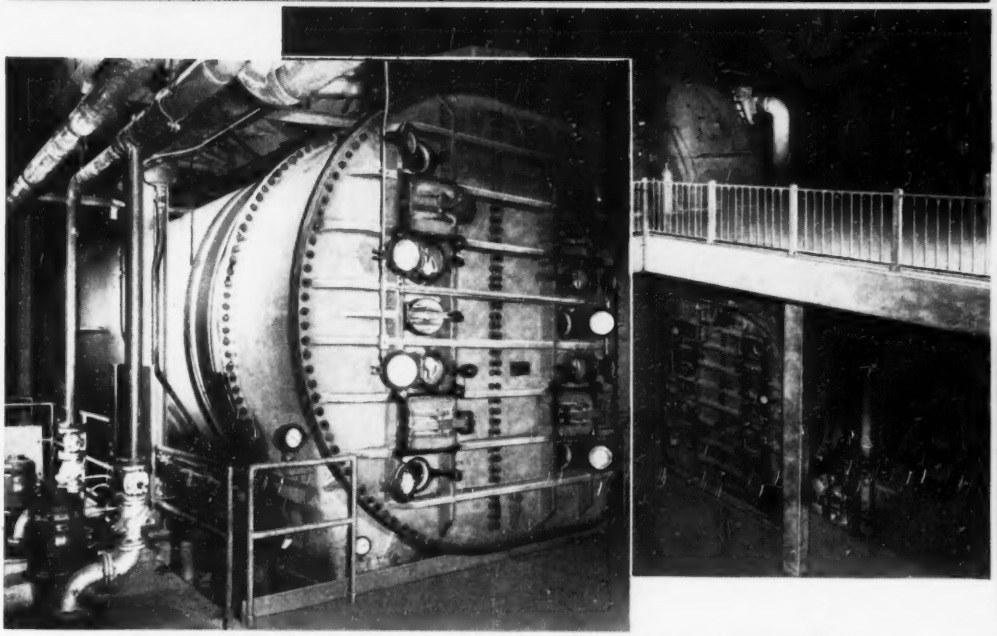
Despite the great achievement of privately owned utilities in the public interest, there is continuing need for greater public awareness of the facts. While this is primarily the job of the utilities themselves, there are opportunities for others to help in making the facts more widely known. To this end, Combustion Engineering—Superheater, Inc., has recently begun an advertising program directed to leaders in business, professional and Government fields. This advertising under the theme "New Power for America" will tell the story of post-war expansion of generating capacity in the various sections of the country. The first ad in the series is reproduced at the left.

C-E

COMBUSTION ENGINEERING—SUPERHEATER, INC.

200 Madison Avenue • New York 16, N. Y.

210,000 Square Feet of Condensing Surface *for* Three 75,000 KW Turbines in One Plant



One of the Three Units for Los Angeles

CONSECO

When Los Angeles added 225,000 KW of generating capacity they also added 210,000 square feet of condensing surface in three condensing units, designed, built and installed by Condenser Service and Engineering Company. Two of the units are now helping to provide service for the expanding requirements of this fast-growing city. Installation of the third unit, now underway, gives ample evidence of very satisfactory performance.

High spots of this installation include:

- **inspection lights which can be used when the unit is in operation.**
- **observation ports provided by manholes designed with quick opening and closing doors. One bolt does the job!**
- **a divided flow design permitting cleaning one-half of the condenser while operating the other half at reduced vacuum.**
- **rolled tubes at both ends, and provided with expansion joint and special steam trunk.**

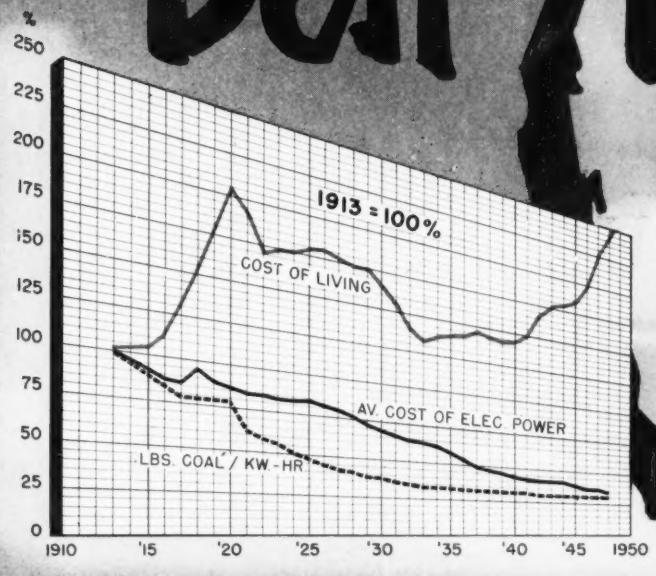
Specialization in this field has stimulated design and other features accepted by discerning buyers in utility and consulting circles.

Condenser Service and Engineering Company is prepared to analyze your requirements and recommend the most economical type to adequately meet your operating conditions. Illustrated literature is available promptly on request.

CONDENSER SERVICE & ENGINEERING CO.

HOBOKEN, NEW JERSEY

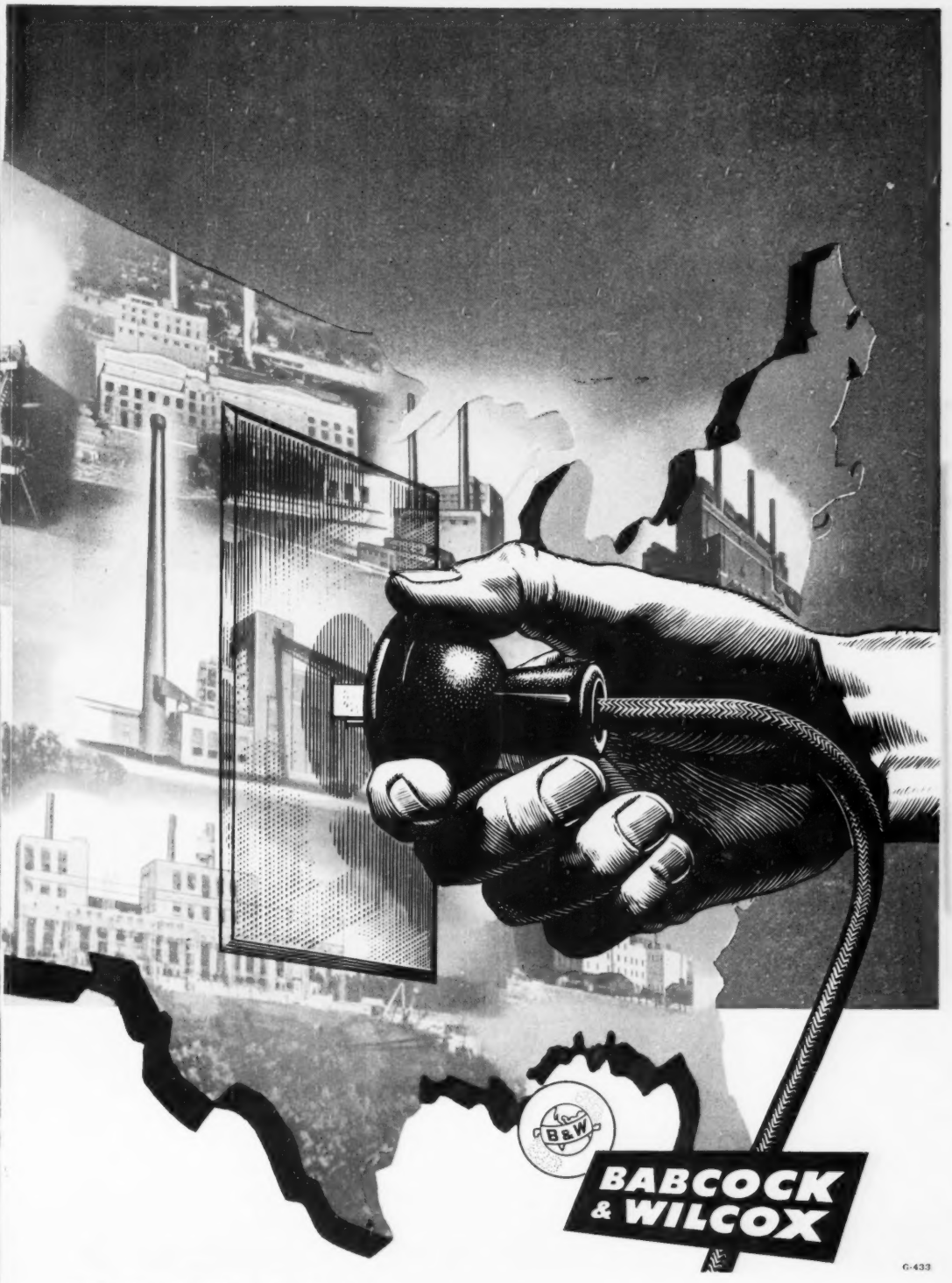
TODAY'S Best Buy ...AND WHY



America's biggest bargain sale has been running continuously for over 60 years — ever since the nation's first central power station was opened. All the while that power companies have been making dependable electric energy more and more plentiful, year after year, they have also reduced its cost to consumers, as shown on the chart above.

Reflected in this steady decline in power rates are decades of co-operative technological progress by power company engineers and manufacturers of steam generating equipment. Included in this progress were many significant improvements developed and perfected by the research and resourceful engineering of B&W. Recognized and accepted by courageous, far-sighted power company managements, these achievements have contributed importantly to making power generation so economical today. For example, less than one-fifth as much coal is now used to generate a kilowatt-hour as in the earliest power stations.

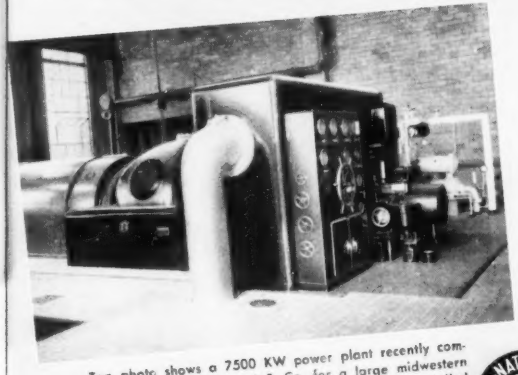
And still the quest continues . . . by power companies and by B&W . . . for new ways of making — and keeping — kilowatts the best bargain in America.



G-433

Pritchard Built **POWER PLANTS***

*Give You Improved Efficiency—Low Cost Power



Top photo shows a 7500 KW power plant recently completed by J. F. Pritchard & Co. for a large midwestern utility. Smaller photo shows a turbo-generator installed in the plant.

Pritchard engineers are thoroughly experienced in constructing power plants in which every detail is designed for more profitable operation. Corporate utilities and industrial users of electric power know that with today's higher labor and supply costs, improved plant efficiency is essential to profit margins. Sound engineering practices, complete design facilities, mutual understanding of your problems and a willingness to cooperate with your engineers, enable Pritchard to achieve that goal for you.

If you are planning any power plants (steam or diesel), generating stations, alterations or expansions it will pay you to consult Pritchard first. Any part of Pritchard's design, engineering and construction service is also available separately. Write TODAY for complete information and competent consultation.

NATIONAL CONSTRUCTORS ASSOCIATION — MEMBER

THREE FUNCTIONS — Design, Engineering, Construction

FIVE FIELDS — Serving the CHEMICAL, POWER, PETROLEUM and GAS industries as well as providing specialized EQUIPMENT for all industries.

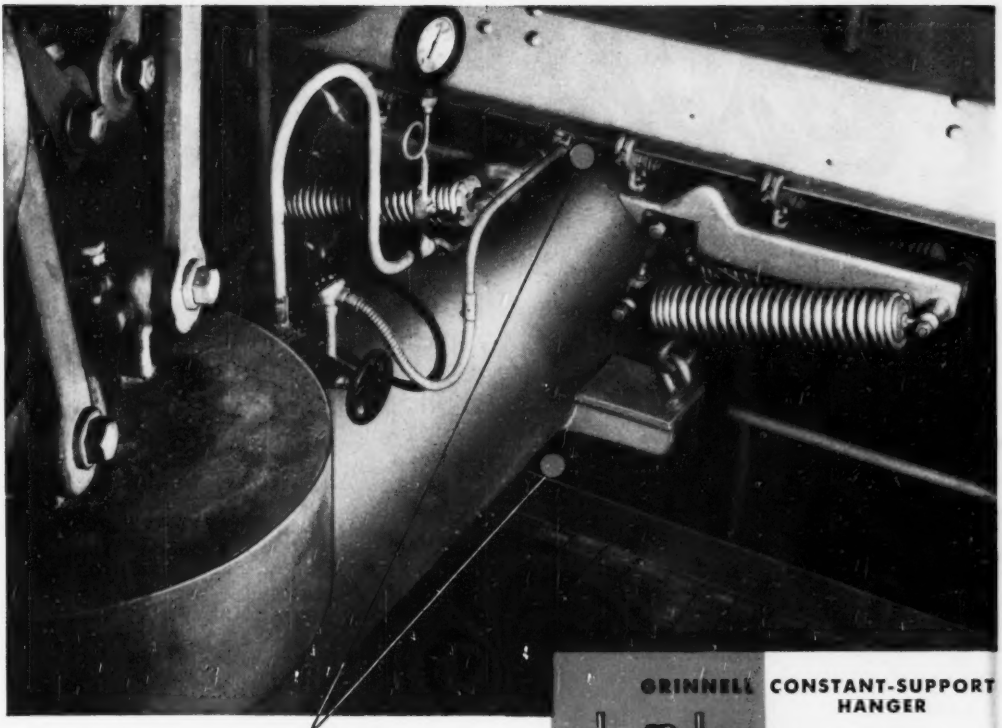
POWER DIVISION

J.F. Pritchard & Co.

DESIGN • ENGINEERING • CONSTRUCTION

908 GRAND AVE. • KANSAS CITY 6, MO.

HOUSTON • NEW YORK
ST LOUIS • TULSA • LOS ANGELES • PITTSBURGH • CHICAGO

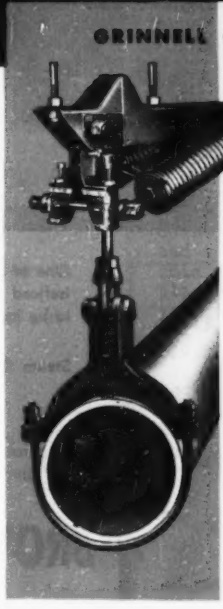


PLAYROOM for a HEAVYWEIGHT

It's a lively chunk of deadweight, this big boiler lead from a superheater outlet at the stop and check valve . . . in the new Southwark station of the Philadelphia Electric Company. It requires "playroom". From its position when cold to its position at 900°F., this piping travels through all three planes — vertical, lateral and longitudinal.

At every point of its travel, the weight of this piping is fully supported by Grinnell Constant-Support Hangers. Yet, because of their compact design, little extra "playroom" need be allowed in which to install the hangers.

Write for the new Grinnell Pipe Hanger Catalog 10-D, containing every pipe hanger, part and accessory, with full instructions for easy selection and correct specification.



GRINNELL CONSTANT-SUPPORT HANGER

the ONLY constant-support pipe hanger

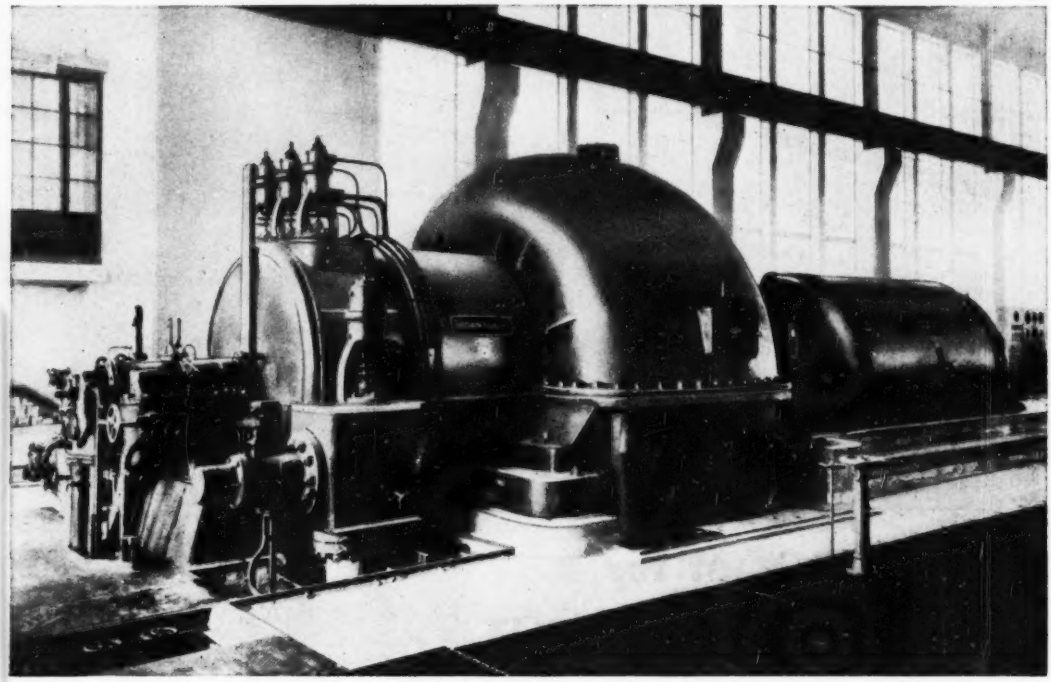
- provides constant support to piping subject to vertical movement — in all "hot" and "cold" positions.
- maintains full safety factor in supporting high temperature, high pressure piping.
- non-resonant and energy absorbing.
- mass-produced from standard precision parts.
- individually calibrated for each installation.
- load-adjustment features incorporated into design.
- three models meet entire range of load-travel specifications.
- minimum headroom required.

99 YEARS PIPING

GRINNELL

Grinnell Company, Inc., Providence, R. I. Branch warehouses: Atlanta • Buffalo • Charlotte • Chicago • Cleveland • Cranston • Fresno • Kansas City • Houston Long Beach • Los Angeles • Milwaukee • Minneapolis • New York • Oakland • Philadelphia • Sacramento • St. Louis • St. Paul • San Francisco • Seattle • Spokane

Cleveland selects



FEATURES OF
BROWN BOVERI
TURBO-GENERATORS

- *High Efficiency*
- *Maximum Accessibility*
- *Compact Design*
- *Faster Starting*
- *Smooth Running*
- *Low Weight*
- *Single Oil System for lubrication and all-hydraulic governing*
- *Long Life*
- *Moderate Cost*
- *Brown Boveri Quality*

One of 3 Brown Boveri single-cylinder double-flow Turbosets operating in Isefjord Power Plant, Denmark, of the same type selected by Cleveland, to be installed in the Lake Road Generating Station, as follows:

2 Turbine-Generator Sets each 25000/31250 kw
Steam Conditions: 650 psig. 825°F Back pressure 1" Hg. abs.
Generator Voltage 11500
Frequency 60 cycles
Speed 3600 r.p.m.

Generators with built-on main and pilot exciters including automatic voltage regulators.

BROWN BOVERI CORPORATION

Progressive Engineers

SWITCHGEAR
- Air Blast Breakers
- Oil Circuit Breakers
- Power Disconnects
- High Speed DC Breakers
- Current Transformers
- Voltage Transformers

REGULATORS
- for Voltage AC and DC
- Current
- Frequency
- Power Factor
- Paper Machines
- Turbine governing

BROWN BOVERI

TURBO GENERATORS

for addition to

MUNICIPAL LIGHT PLANT

Cleveland saved nearly half a million dollars by selecting Brown Boveri Turbo-Generators . . . but it was not entirely a question of economy that dictated their choice.

Brown Boveri efficiency and reliability are known the world over. There are in the United States some 25 Brown Boveri turbo-sets, many of which have been in service for more than 20 years . . . and 14 in Canada, installed under the supervision of specialized Brown Boveri Engineers. None of these units has ever been out of operation due to lack of spare parts and service.

It will pay you to invest in Brown Boveri equipment.

A Brown Boveri Client in the USA writes:

(Jan. 7, 1949)

"We have placed, with your Company, orders for many turbogenerating units. . . . We have found your erection and service engineers highly qualified and competent men . . . even during the recent war we were able to obtain replacement parts for your machinery . . . we had confidence in obtaining these replacements as we knew you had drawings for all parts involved and same could be manufactured in this country, if not available from Switzerland."

19 Rector Street, New York 6, N. Y.

—Skilled Craftsmen—for Over 50 Years

RELAYS
- Current, Voltage, Power
- Thermal
- Differential
- Ground Fault
- Distance
- Buchholz

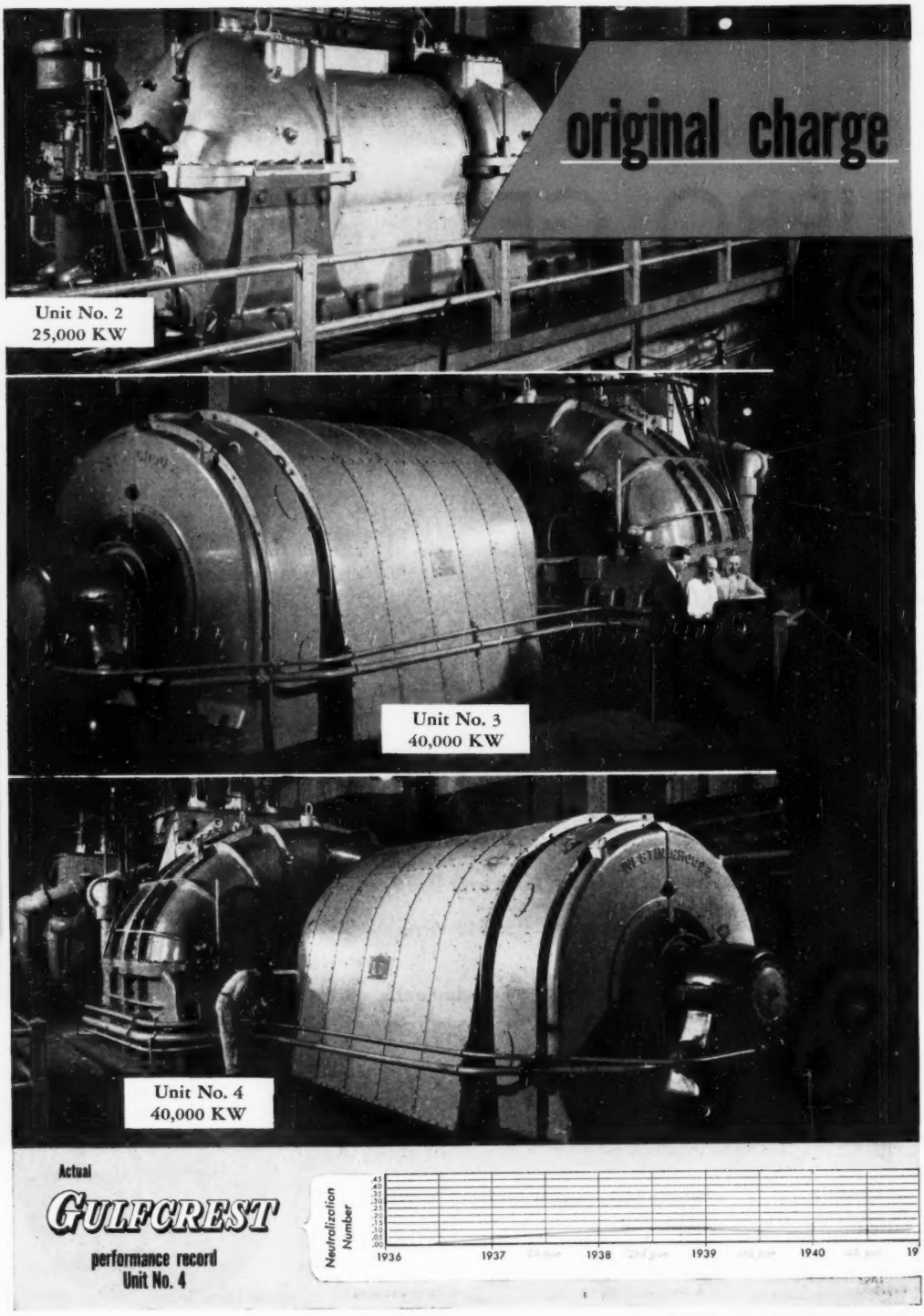
MOTORS AND TRANSFORMERS

All Type Motors
- constant & variable speed

All Size Transformers
- fixed ratio & load tap changing

TURBINES
- Gas Turbines
- Steam Turbines
- Marine Turbines
- Centrifugal Compressors
- Axial Blowers
- Turbo Chargers

BROWN BOVERI


original charge
Unit No. 2
25,000 KW
Unit No. 3
40,000 KW
Unit No. 4
40,000 KW
Actual
GULFCREST
performance record
Unit No. 4
Neutralization Number
1936
1937
1938
1939
1940

# of GULFCREST OIL

has *12-year record* of outstanding performance in 40,000 and 25,000 KW Turbines

Over 12 years of service and still providing outstanding lubrication — that's the performance record of Gulfcrest Oil in these three big turbines! Additional evidence that Gulfcrest Oil lasts indefinitely!

Typical of the neutralization number curves for these units is the one shown below for Unit No. 4. Note the consistently low neutralization number of Gulfcrest Oil during and after this remarkably long service.

As a result of outstanding operating experience with Gulfcrest Oil, it has been selected by this important utility for each successive new turbine installation since 1937 — today every unit in the system is lubricated with Gulfcrest!

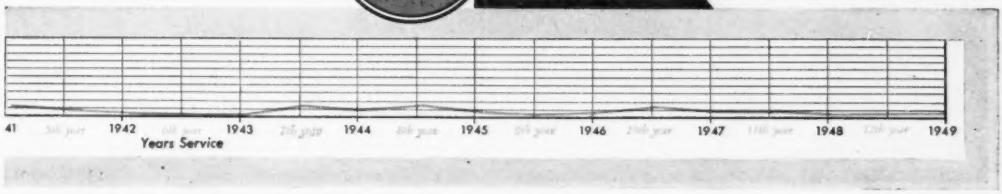
Here's the important reason for operating records like this with Gulfcrest Oil: extra refining by the Alchlor Process which not only removes more of the sludge formers than any other refining method, but imparts to the oil greater ability to benefit from the addition of special inhibitors.

Call in a Gulf Lubrication Service Engineer and ask him to show you how Gulfcrest Oil can help you get improved lubrication and higher operating efficiency for your turbines. Write, wire, or phone your nearest Gulf office today.

Gulf Oil Corporation • Gulf Refining Company

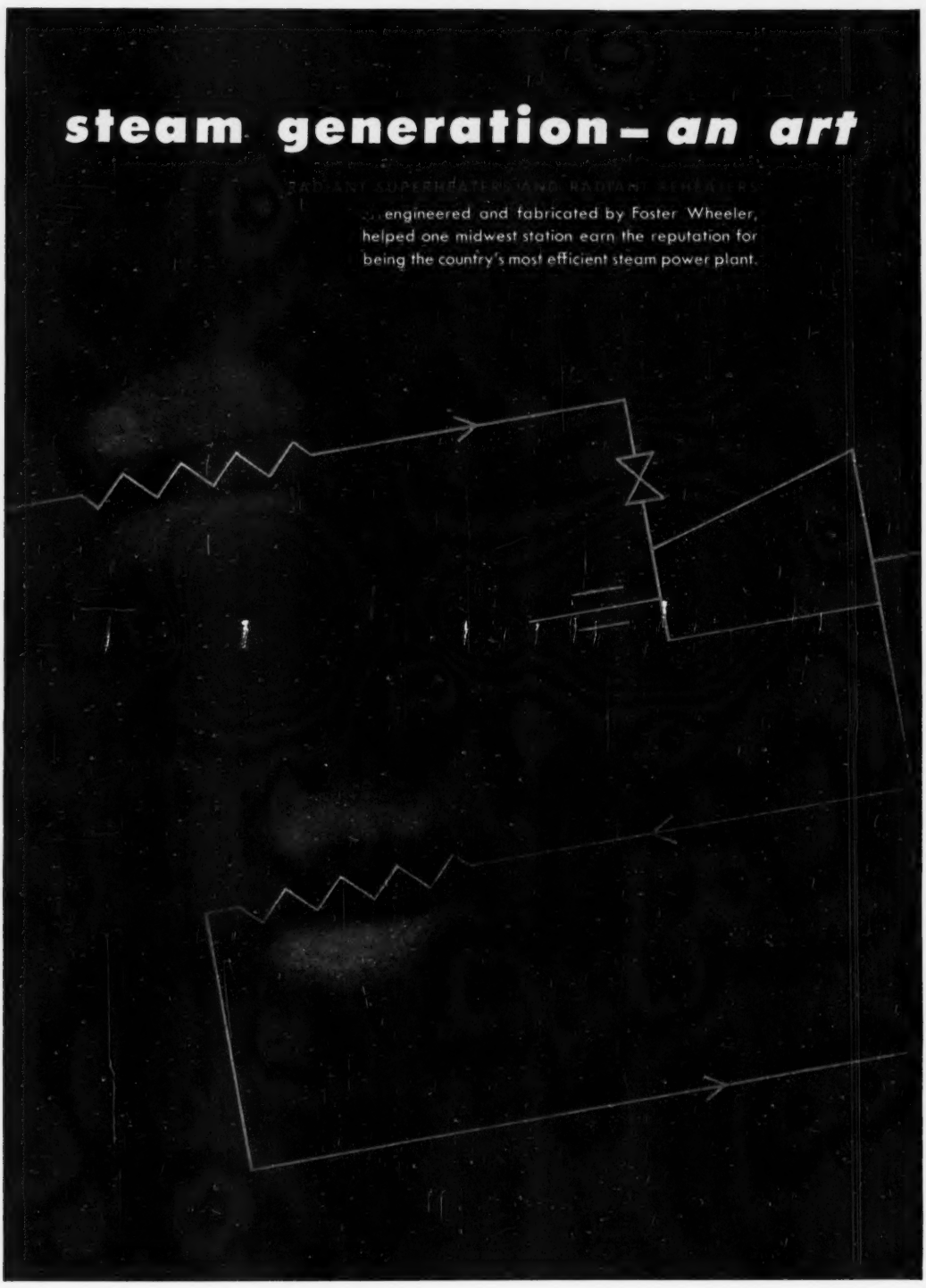
Division Sales Offices:
Boston • New York • Philadelphia • Pittsburgh • Atlanta
New Orleans • Houston • Louisville • Toledo

GULF INDUSTRIAL LUBRICATION



steam generation – *an art*

... engineered and fabricated by Foster Wheeler, helped one midwest station earn the reputation for being the country's most efficient steam power plant.



The Foster Wheeler organization has devoted over fifty years to improving steam generation technique and steam power plant equipment. A few of FW's historical achievements are listed below:

1898 Pulverized fuel was developed on a commercially successful scale.

1902 Superheated steam was introduced commercially in the United States.

1919 Radiant superheaters were developed after long research and development.

1924 Water walls and water backs were applied to many types of furnaces burning various fuels.

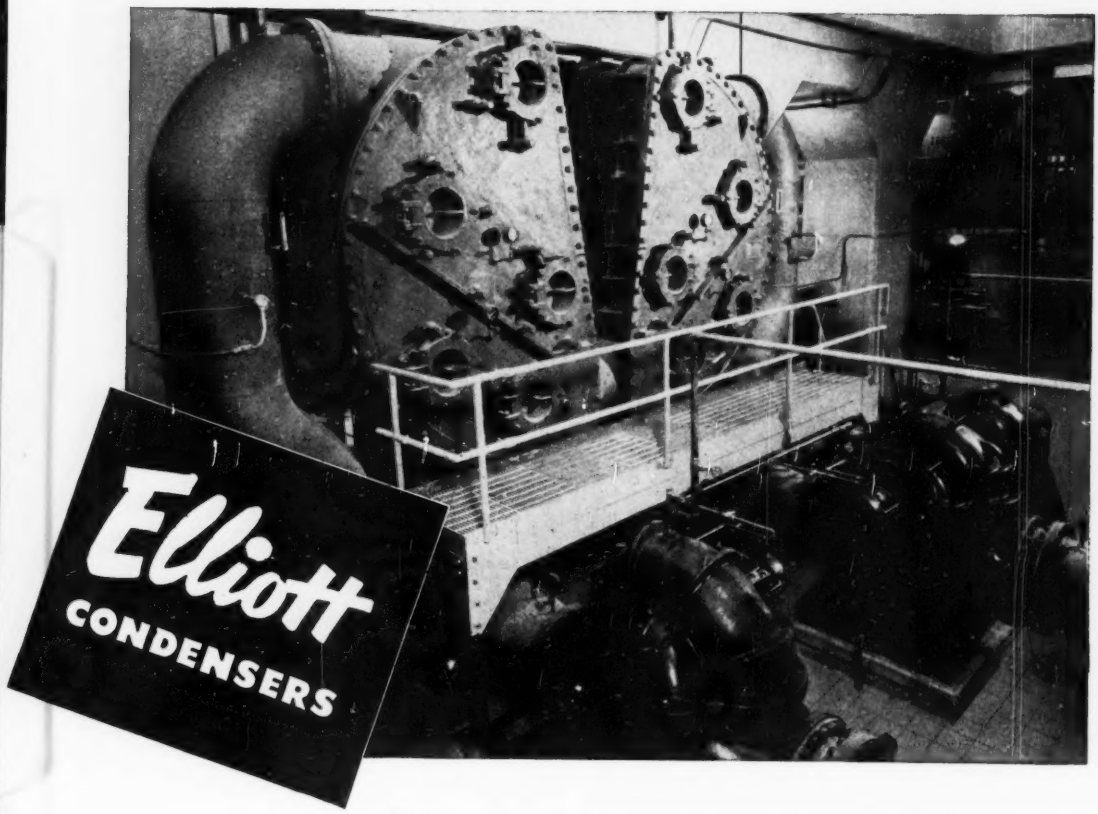
1946 The first large steam generator in a utility plant to operate at 1000° F over a wide load range was installed.

TODAY All the engineering, manufacturing, and construction activities of the Foster Wheeler organization are geared toward helping build the better power plants of today and tomorrow.

FOSTER WHEELER CORPORATION · 165 BROADWAY, N.Y. 6, N.Y.

FOSTER WHEELER

2 big factors IN PROFITABLE



In keeping with the experience of more than thirty years, Elliott condenser design sets a high standard which is proven beyond question by many condenser installations throughout the country.

The 30,000-sq. ft. divided water-box surface condenser illustrated above is one of two serving a fine new station of an Eastern utility. The condensers are equipped with reverse-flow valves.

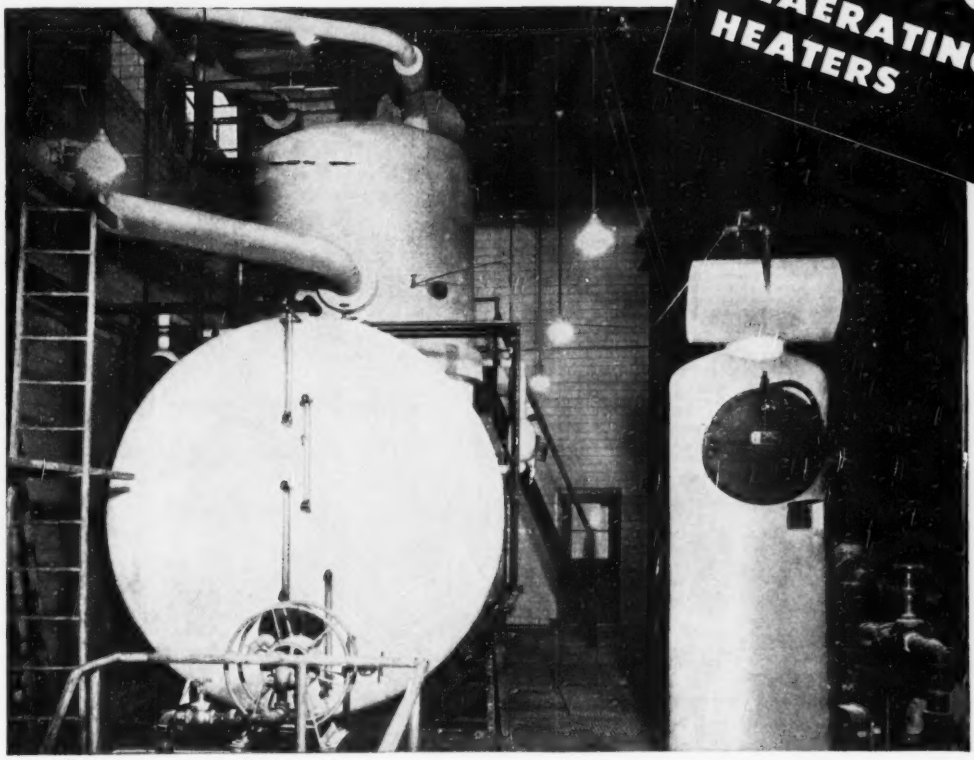
Elliott condenser design permits of wide modification to meet specific requirements. Condenser Bulletin C-9 at request.

ELLIOTT COMPANY

Heat Transfer Dept. and
Deaerator & Heater Dept.
JEANNETTE, PA.

STEAM PLANT OPERATION

Elliott
DEAERATING HEATERS



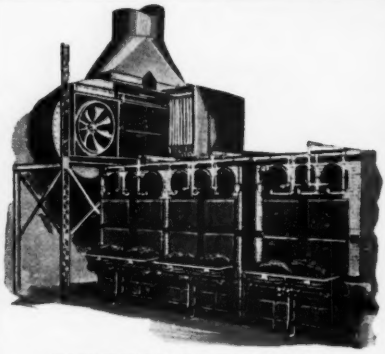
Again experience pays off. Elliott engineers pioneered in deaerating heater development, and have consistently set the pace in the design of this type of equipment, now a major essential in steam plants.

The installation above serves the same plant as the condenser on the facing page. The large horizontal storage tank is surmounted by a vertical 375,000-lb.-per-hr. deaerating feedwater heater. The vertical unit at right is a 14,000-lb.-per-hr. deaerating evaporator preheater handling make-up requirements. Bulletin N-16 gives full deaerating heater details.

Q-1140

"Buffalo" DRAFT FANS "Grew Up" with the POWER PLANT!

50 YEARS AGO advertisements like this kept engineers abreast of this development for increasing boiler capacity.



BUFFALO INDUCED DRAFT PLANT AT HOBOKEN, N. J.

THE Buffalo Mechanical Draft System is the essential factor of advanced boiler practice. Is easily installed, flexible, positive and instantaneous. Makes feasible an increase of capacity without enlarging the boiler plant

ASK FOR BOOKLET CT.

BUFFALO FORGE CO.

ENGINEERS AND MANUFACTURERS.

BUFFALO. NEW YORK. CHICAGO.

CANADIAN BUFFALO FORGE CO., LTD., MONTREAL.

High Speed Engines. Fan System of Heating and Ventilating. Steel Plate Fans. Steel Pressure Blowers.

Id 1.

Here's RELIABILITY Backed by 71 Years Of Fan Engineering

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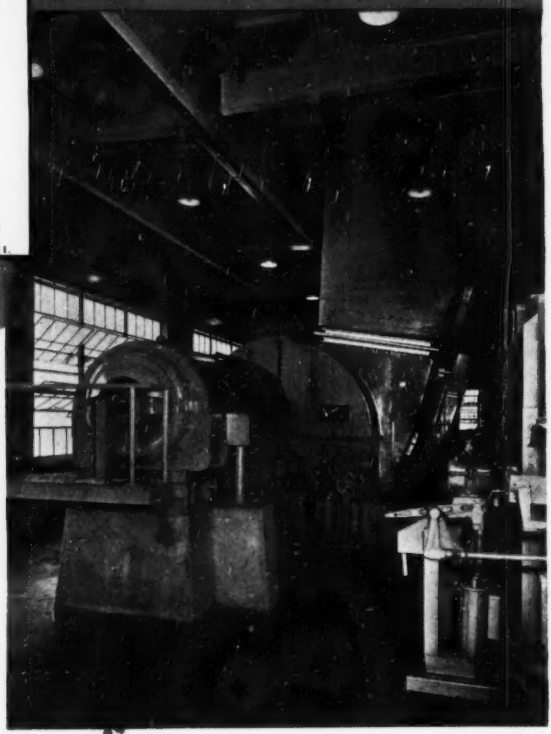
That's why you can be sure of best draft service when you specify "Buffalo" for induced draft, forced draft or primary air. "Buffalo" Fans have been proving themselves since the earliest mechanical draft installations. And the performance of every "Buffalo" fan you buy is backed by 71 years of "air experience". Call in your "Buffalo" representative for facts on this PROVEN draft service!



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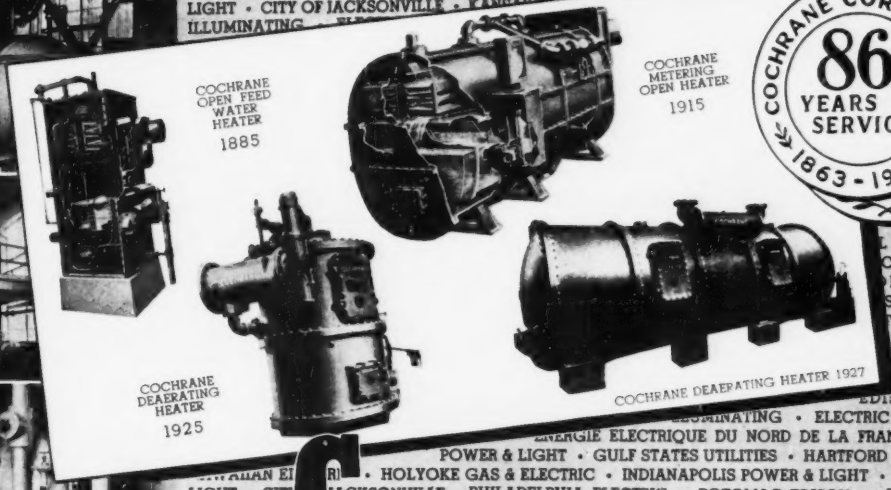

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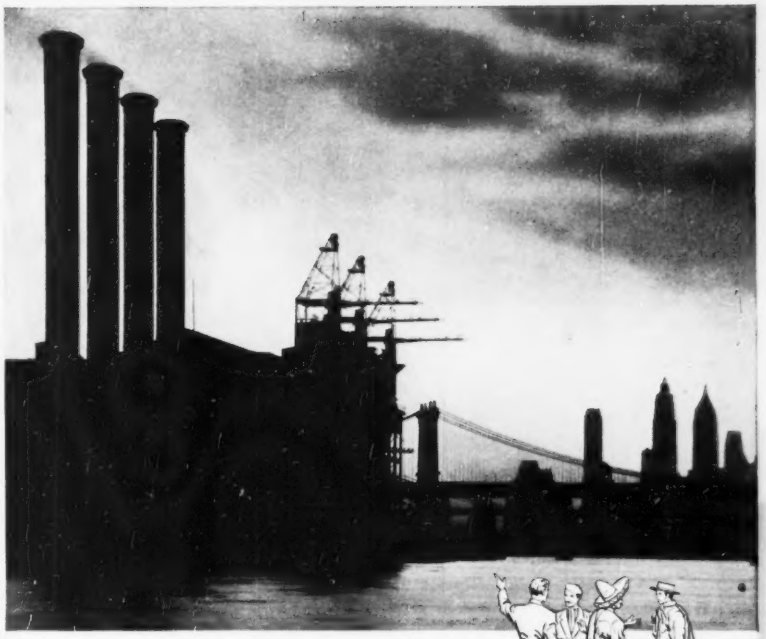

What José tells Joe

WORD certainly gets around.

Kellogg's only fabricating shop for high pressure and high temperature piping is in Jersey City. Yet orders for power piping continue to come not only from the logical sales areas but also from Europe, Central America, South America and from half a dozen different geographical centers in the U. S. A.

Why? The answer we like to believe is that the word gets around that Kellogg installations leave no undesirable after-taste, that, to use a prosaic phrase, they leave only satisfied customers. And they should, because "built into" each installation are certain factors that virtually guarantee better than average performance and service life.

For example, there's extensive "creep-testing" of high temperature materials being conducted in Kellogg's metallurgical Laboratory. And there's the concurrent, continuous study of *graphitization.*

There's the exclusive apparatus for the *determination of stresses* in complicated piping installations. There are the *shop fabricating techniques* and *shop quality check system* that are considered among the best in industry.

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And beyond these, there are *more than thirty years* of successful completion of the highest temperature and highest pressure power piping – including installations in some of the world's largest power plants.

These are the reasons why the word about M. W. Kellogg power piping gets around when José talks to Joe, or whenever and wherever in the world power men meet.

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COMPLETE DRAFT PRODUCING FOR ANY SIZE BOILER

The Thermix Fan Stack is composed of a fan, breeching and stack, forming a complete draft-producing unit in packaged form. The manufacturers, Prat-Daniel Corporation, East Port Chester, Connecticut, state that its advantages lie in the fact that efficient draft is dependent on the coordination of these three components . . . the fan, breeching, and stack. In the Thermix Stack, all three are designed to balance each other, thus achieving smooth operation of the unit as a whole. Breechings of Thermix Stacks are a straight line, eliminating inherent reductions in efficiency due to bends. The divergent shape of the stack converts velocity pressure to static pressure, increasing the efficiency of the unit.

Sold as a complete packaged unit, this stack may be mounted directly on the boiler and is manufactured in a wide variety of sizes to accommodate almost any horsepower boiler.

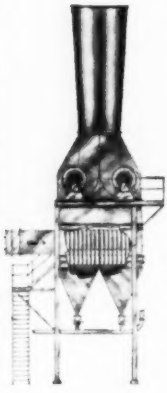
ADVANCED TYPE OF UNIT HEATER OFFERED BY PRAT-DANIEL

THERMOBLOC is a new design in Packaged Direct-Fired Unit Heaters, manufactured by the THERMOBLOC DIVISION of Prat-Daniel Corporation, East Port Chester, Connecticut. Applicable to heating large or small plants, this unit will provide an automatically controlled supply of heat at just the right temperature required. No ducts or steam pipes are required. This feature eliminates the possibility of freezing during shut-downs in winter and THERMOBLOC's instantaneous firing makes banking at night unnecessary. Heated air is circulated at working level and does not depend on a gradual building up of warm air from the ceiling down. During the summer, this unit may be used to circulate cool air, drawn from the floor level, to working level.

Two sizes are available. The THERMOBLOC 300, delivers 300,000 b.t.u.'s per hour, is 30" in diameter and 7' high. The THERMOBLOC 550, delivers 550,000 b.t.u.'s per hour, is 30" in diameter and 10' high. Both models are admirably adaptable to on-the-job construction heating because of their packaged feature requiring only the hooking up of power and fuel lines to place the unit in operation. Full details are available on request.

There are all kinds of

DUST COLLECTORS



. . . But, when you're looking for a collector that has high efficiency, occupies a minimum space and is manufactured and backed by a name known to the power field for over 25 years, it will pay you to investigate the Thermix Tubular Collector.

Composed of multiple, small diameter tubes that not only provide higher efficiencies, but permit appreciable reductions in space, Thermix Tubular Dust Collectors have fitted into many plant designs that could not have accommodated a larger unit.

Thermix Fan Stacks, a complete draft-producing unit, offer the ideal complement to the Thermix Tubular Collector. Together these units provide a complete predetermined control of draft and dust . . . designed, engineered, manufactured and guaranteed by one company.

Write our project and sales engineers for the answer to your draft problems.

Sales and Project Engineers for Power Plant Division

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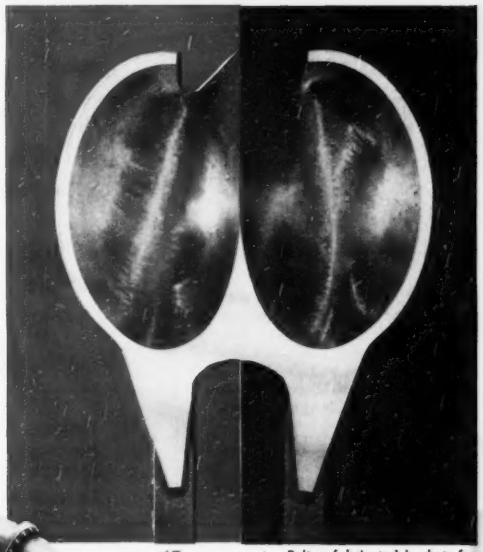
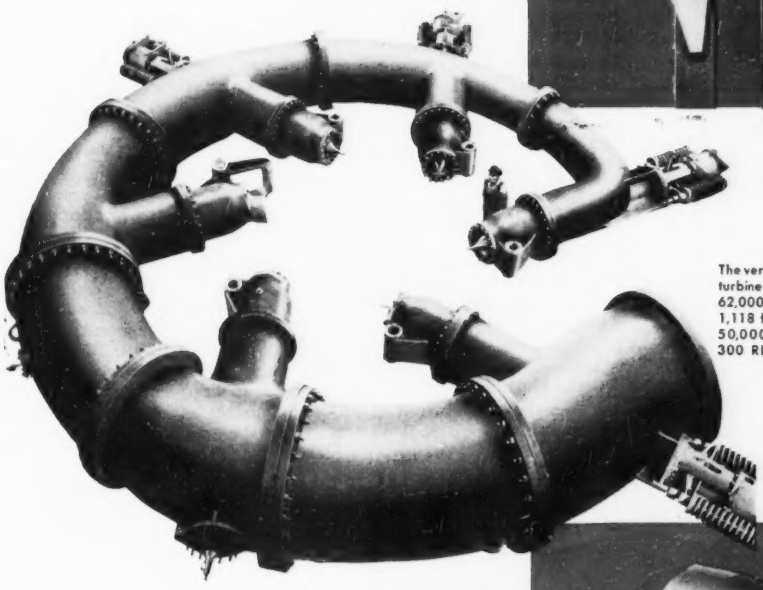
PIONEERS IN POWER DEVELOPMENT

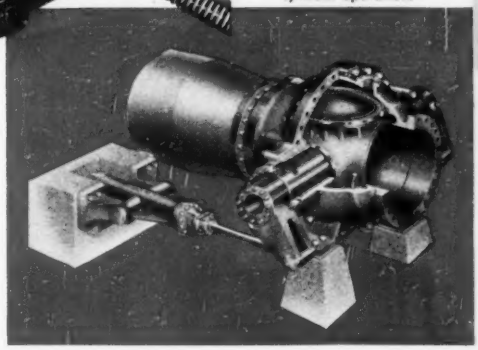


Pelton fabricated buckets for runners are formed of heavy plate steel and welded, providing a smoother, less porous wearing surface than cast buckets. The result is better utilization of water power and greater efficiency.



The vertical, six nozzle impulse turbine illustrated will produce 62,000 HP under a head of 1,118 feet, and will drive a 50,000 KVA generator at 300 RPM.

Pelton spherical valves are available in sizes from 6 to 72 inches, with handwheel, electric motor or hydraulic cylinder operation.



For more than 65 years, The Pelton Water Wheel Co. has maintained leadership in the engineering of power projects.

In the design and manufacture of hydraulic equipment for waterworks and hydroelectric installations, Pelton has made many notable contributions to the more efficient control and utilization of water power.

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2468	1849
2395	1800
2180	1795
1894	1750
1890	1745
1868	1700

Pumping boiler-feed water 24 hours a day, at discharge pressures up to 3000 psi, is a tough job for any pump. It's a job that calls for extra stamina and endurance—for trouble-free performance year after year.

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HERE ARE SOME OF THE REASONS FOR THIS PREFERENCE

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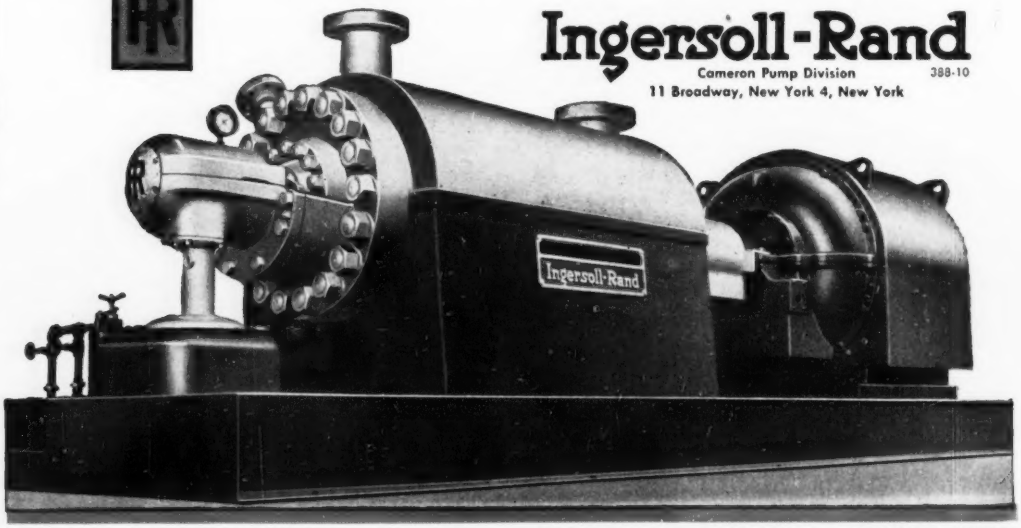

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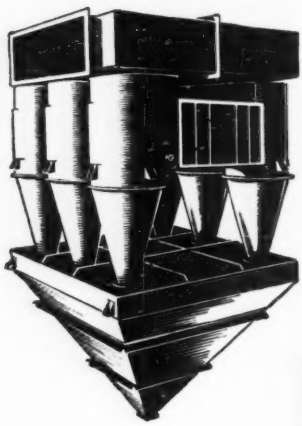

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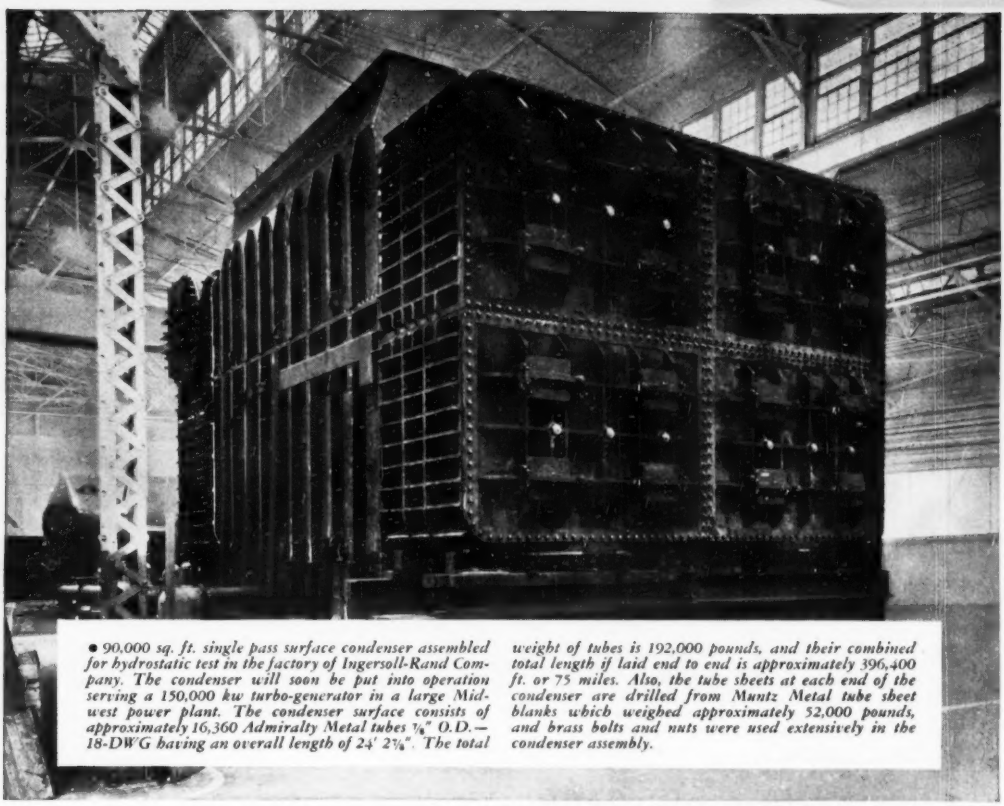

• 90,000 sq. ft. single pass surface condenser assembled for hydrostatic test in the factory of Ingersoll-Rand Company. The condenser will soon be put into operation serving a 150,000 kw turbo-generator in a large Midwest power plant. The condenser surface consists of approximately 16,360 Admiralty Metal tubes ⅞" O.D.—18-DWG having an overall length of 24' 2⅞". The total weight of tubes is 192,000 pounds, and their combined total length if laid end to end is approximately 396,400 ft. or 75 miles. Also, the tube sheets at each end of the condenser are drilled from Muntz Metal tube sheet blanks which weighed approximately 52,000 pounds, and brass bolts and nuts were used extensively in the condenser assembly.

Photo courtesy of Ingersoll-Rand Company, 11 Broadway, New York 4, N. Y.

ELECTRICITY CAN BE CORROSIVE, TOO

OPERATORS of condensers are well-informed and follow sound general practices that should result in satisfactory tube life, but it has been estimated that in about 90% of American plants there is at least one piece of equipment that shows tube trouble. Such cases interest Revere greatly, because we want condenser tubes to give satisfactory, economical service.

Sometimes the causes of premature failure are obscure and difficult to discover. One of them is stray electricity. When you remember that copper plating is usually done at about 4 to 6 volts, you can see that it doesn't take much to move metal from one place to another through a fluid. Any flow of current through a condenser is sure to be destructive.

Electricity often finds strange routes to ground through high-resistance shorts that do not show up through blown fuses, overheated parts, arcing, and similar obvious indications. Pump motors, for example, may work perfectly well, but permit a little "corrosive" electricity to pass along to ground through the condenser; electrolysis results. Galvanic action, due to the use of metals of too-great dissimilarity, may also occur, but is rare in a condenser properly designed for its operating conditions.

So Revere suggests you include electricity as a possibility when seeking the causes of unexpected tube failure. And it is also advisable to save samples cut from failed tubes, to be sent to Revere for laboratory examination. Facts thus scientifically uncovered may lead to recommendations that will solve the problem. If you have a condenser tube problem, ask Revere to help.

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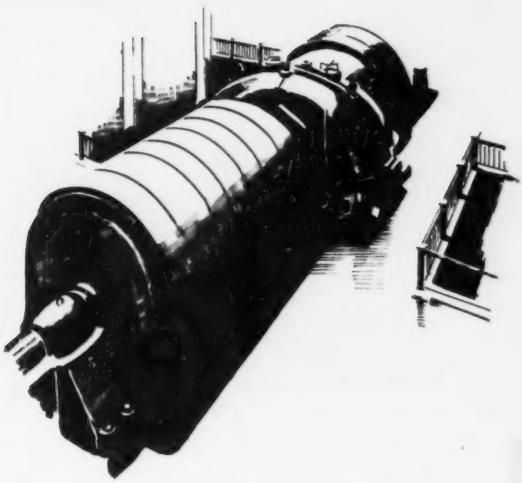

STATION GENERATION

TURBO AND HYDRO ALTERNATORS

STATION BUS PATTERNS

PROGRESS IN POWER SWITCHGEAR

INTERCONNECTION AND SYSTEM CONTROL

No less significant than what has evolved in the mechanical side of the generating station is the improvement achieved from the electrical side of the alternator coupling on through the station to the power take-away facilities. Ratings and dependability of alternators have been increased along lines conducive to economy as well as security. As number and size of units grew, the limitations of earlier bus arrangements led to exigencies which prompted alternative schemes with better flexibility and performance. Above all, the "crowding" of switchgear interrupting abilities resulted in mishaps that made bigger and better circuit breakers inescapable and inevitable. Meanwhile stations had multiplied to the point of logical interconnections, bringing fresh influences to bear on generator, bus and switchgear performance. How these segments of the power system have marched ahead coordinatedly is the theme of the ensuing papers.

PUSH OUT
AND FOLD

Contributors to Station Generation Section

C. W. Franklin

Turbo and Hydro Alternators

Mr. Franklin is Electrical Engineer of the Consolidated Edison Co of New York, Inc, in charge of electrical design for generating stations and substations, and the transmission and distribution systems in New York City. He is a Fellow of the AIEE. He has served in various capacities on committees of the AIEE, NELA, EEI, AEIC and New York State Society of Professional Engineers. He is author of a number of technical papers.

R. T. Henry

Station Bus Patterns

Mr. Henry is chief electrical engineer, Buffalo Niagara Electric Corp, has been vice-president and director of AIEE and chairman of the AIEE standards committee. He has also been chairman and long-time member of the EEI Electrical Equipment Committee, is member of the Joint EEI-AEIC-NEMA Committee on Circuit Breakers and the EEI-AIEE-NEMA Committee on Coordination of Insulation. He has authored numerous articles in AIEE and ELECTRICAL WORLD.

R. W. Wilbraham

Progress in Power Switchgear

Mr. Wilbraham is Chief Electrical Engineer of United Engineers & Constructors Inc. He has been designer and constructor for over thirty-five years of generating plants, transmission and distribution systems, electric railways and industrial electric systems, including many major projects involving new developments. In 1936 he served as chairman, Electrical Round Table, Third World Power Conference. A native of Philadelphia and a graduate of the University of Pennsylvania, he is past chairman and member of EEI Electrical Equipment Committee, AEIC Committee on Electric Switching and Switchgear, and member of EEI-AEIC-NEMA Joint Committee on Power Circuit Breakers; Fellow of AIEE; author of numerous papers.

H. Webster Phillips

Interconnection and System Control

Mr. Phillips is supervisor of the Pennsylvania-New Jersey Interconnection and has been chairman of the Systems Operation Committee of the Pennsylvania Electric Association. He is a member of AIEE and also of the Engineers Club in Philadelphia. He has to his credit several papers on interconnection operation and accounting.

Turbo and Hydro Alternators

Hydrogen supplants air for cooling. Rotors capable of 3,600 rpm. Field temperatures and distortion. Stators adapted to 3,600 rpm and insulation improved. Comparative European practice, particularly 33-kv machines Evolution of overhung or umbrella-type hydro units

In 1924 TURBO GENERATORS had already experienced a five-year period of rapid technological developments. Steam power plants were planned up to an ultimate capacity of 400,000 kw. Generators rated 50,000 kw at 1,200 rpm were in operation. Such a machine is shown in Fig 1. Central station design engineers were pressing the manufacturers for larger and more efficient generators.

Generator Cooling

At that time all generators were air cooled. As the machines became larger uniform ventilation became a problem, which was attacked vigorously by theoretical and experimental investigation of the air flow and the heat transfer characteristics of the air passages in rotors and stators. New fan designs were developed. By 1930 the majority of new large turbo generators used a design wherein the cooling air enters the core ducts at the back of the generator stator in multiple radial paths, moves a short distance axially along the air gap, and leaves the machine radially in another group of multiple paths in the stator core.

In the larger machines the rotor winding ventilation was improved by forcing cooling air into ducts below the bottom of the slot and exhausting it through small radial holes into the air gap. Field rotor ventilation was also improved by grooving the rotor surface.

Hydrogen Cooling

The first commercial applications of hydrogen cooling were made on synchronous condensers manufactured in 1927. The hydrogen seal development was a "must" for generators and soon reached the stage where its commercial application in large units became feasible.

The first hydrogen cooled 3,600-rpm power plant turbo generator was placed in service at Miller's Ford Station of Dayton Power and Light Co, Dayton, Ohio, on October 12, 1937. The machine was rated 25,000 kw, 31,250 kva. A number of these units were installed within the next year, the largest being rated 53,000 kw, 3,600 rpm, 13.8 kv.

The gas seal was accomplished by the use of a ring of oil maintained under pressure between the generator shaft and the bearing housing. Though the use of hydrogen began at approximately ½ psi gauge pressure, housings suitable for withstanding internal explosions without permanent distortion were provided.

Although hydrogen cooling was first used on a 3,600-rpm machine, where reduction of windage loss would be most effective, it was later applied on a large single shaft 1,800-rpm generator rated 176,500 kva. The advantages of hydrogen justified its use at the lower speed for machines of higher kva capacity. During the early days of hydrogen cooling, it was considered that the smallest 3,600-rpm machine which could justify its cost was 30,000 kw. Since World War II this rating is 15,000 kw, due to simplification in the hydrogen control equipment. A typical hydrogen control system is shown in Fig 2.

Hydrogen cooling and higher speed provide economy in both weight and space requirements, often as much as 50% gain.

Generator Rotor Forgings

The element of turbine driven generators, which limits capacity is the material strength in the main rotor body and in the end retaining rings. As a result of improvements in the strength of these materials, large generator rotor speed was increased from 1,200 rpm to 1,800 rpm about 1925. The rate at which machine capacity was increased, following the development, is shown in Fig 3.

Two of the largest single shaft machines manufac-

Prepared by C. W. FRANKLIN, *Electrical Engineer, Consolidated Edison Co of New York, Inc*

with the collaboration of L. Birckhead, Consolidated Gas Electric Light & Power Co of Baltimore; R. T. Henry, Buffalo-Niagara Electric Corp; E. W. Knapp, The Shawinigan Water & Power Co; C. M. Laffoon, Westinghouse Electric Corp; S. H. Mortensen, Allis-Chalmers Mfg Co; H. D. Taylor, General Electric Co; B. Van Ness Jr., Safe Harbor Water Power Corp; H. B. Wood, Stone & Webster Engineering Corp; G. R. Woodman, Southern California Edison Co; J. G. Noest, Consolidated Edison Co of New York, Inc; R. L. Webb, Consolidated Edison Co of New York, Inc

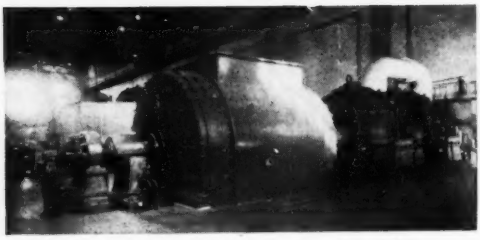

FIG 1—1924 INSTALLATION of a 62,500-kva, 1200 rpm air cooled turbogenerator. Hydrogen cooling appeared later

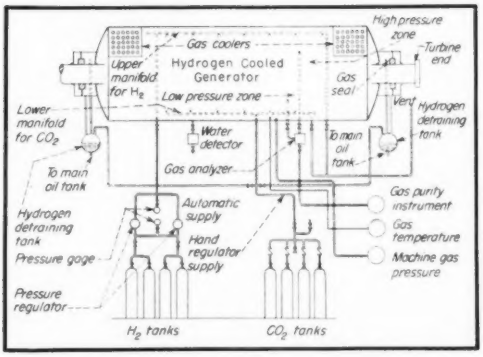

FIG 2—SCHEMATIC hydrogen-control system for turbogenerator. Hydrogen control systems are steadily being simplified

tured, up to the present time, were built in 1931. Each of these machines was rated 200,000 kva, 16.5 kv, 1,800 rpm, 0.8 P.F. The largest multiple unit machine built in the United States was constructed about 1927, with one 76,000-kw, 22-kv. high pressure, two 62,000-kw, 22-kv low pressure generators and two 4,000-kw house service generators. This triple-compound unit has an overall rating of 208,000-kw, 0.85 P.F. The largest single generator in terms of kilowatt rating was placed in service in 1935. It is rated 165,000 kw, 183,333 kva 0.9 power factor, 1,800 RPM and 13.8 kv.

The largest 3,600-rpm machine in 1929 was 15,625 kva. Improvements in materials and design now permit the construction of a hydrogen cooled unit rated 110,000 kw, 129,500 kva at 13.8 kv and one-half psi hydrogen pressure; this machine is now being built.

The lack of mechanical symmetry in the two-pole rotors created double frequency vibration. This was overcome by machining the rotor pole faces, to equalize the moments of inertia of all planes through the axial center.

Field Windings

Field windings for turbogenerators are formed with strip copper shaped to fit into the rotor slots. The coils are insulated with Class B materials throughout. The field rotors of larger generators are longer and have greater diameter. The greater length requires greater total movement of the copper for a given temperature change, while the increase in diameter causes a greater clamping action due to higher centrifugal forces. Several field winding failures occurred due to winding copper distortion caused by these conditions. An example of this is shown in Fig 4.

This type of winding distortion causes turn-to-turn short circuits and eventually produces winding-to-ground short circuits. Winding-to-ground short circuits occurred more readily in a design using aluminum saddles and aluminum blocks to hold the field end windings in position. This design has been abandoned.

Some users adopted a program of preheating the field winding before starting the generator, to reduce the effect of this copper expansion. The manufacturers adopted the use of cold worked copper alloys which can better resist the stresses imposed and changed the end turn construction as shown in Fig 5.

Aluminum Tried

Aluminum with its relatively high conductivity and its low specific gravity, appeared to be the solution of the problems connected with centrifugal force encountered on 3,600-rpm generators. However, its poor physical properties, its greater coefficient of thermal expansion, and the difficulties of making electrical connections, soon accentuated the problems connected with its use and led to renewed efforts in the development of better copper alloys.

The high field current requirements in large generators caused troubles with "selective action" between the collector ring brushes, operating on smooth collector rings. In 1931 a new collector ring construction was adopted to eliminate this difficulty. The ring surface was machined to have a spiraled groove. As the shaft rotates, the spiraled surface of the ring wipes across the carbon brush continuously, thereby avoiding the "selective action."

Stator Frame and Core Construction

In 1924 many parts of the supporting structure and generator frame were of cast construction. With the improvement of welding techniques, manufacturers adopted the use of steel frames fabricated by welding, greatly reducing the weight and the volume of the completed machine. This procedure permits the shipment directly from the factory of larger completely assembled generators.

Laminated silicon core iron was in use before 1924. Research has made it possible to improve the magnetic characteristics of the iron and to reduce its magnetic losses without loss of the required physical properties, resulting in improved generator efficiency. The use of non-magnetic core tooth clamping fingers and other parts at the end turn area further reduced generator losses.

In the early 3,600-rpm machines, difficulty was experienced with stator frame and core vibrations. To overcome this, it was necessary either to stiffen the structure or to provide a flexible mounting for the core. Both methods have been used (Fig 6).

All turbogenerator stator windings use Class B insu-

lation, consisting of mica tape with outer layers of spun glass tape serving as a binder.

As generator voltages were increased, winding failures due to corona cutting of insulating varnishes and tapes were experienced. This has been overcome by using some type of medium resistance coating over the surface of the bar section in the slot. This coating avoids sharp points of high dielectric stress along the bar. This principle was developed later to improve the voltage gradient from the stator iron to the end windings by use of a higher resistance coating on the winding for a short distance beyond the core iron. Generators with armature windings rated 16,500, 18,000 and 22,000 v were manufactured successfully in the late twenties. These are the highest voltages used in generator windings in the United States up to the present.

Organic stator winding binding cords have been replaced by fibre glass cord to reduce cord failures due to corona action and rotting.

Double Windings

Multiple turn coils gave place to single turn designs in large machines. The copper strands were transposed along the slot to avoid voltage differences between them. This permits the use of single bar construction and the connection of all strands together at both ends of the bar, which makes for easier assembly of long heavy windings.

The stator winding current rating of large generators exceeded the carrying capacity of the largest circuit breakers in the late twenties. This was overcome for a 160,000-kw machine by use of two separate stator windings arranged for independent loading on separate bus sections. This not only solved the circuit breaker problem, but provided reactance between the two circuits, thereby reducing the required amount of station bus tie reactance.

Design Characteristics

Generator efficiency was increased during this twenty-five year period by means and in amount as given in the following tabulation:

Year	Generator Description	Per Cent Efficiency
1924	62,500 Kva 1,200 rpm air cooled	97.2
1931	200,000 Kva 1,800 rpm air cooled	98.4
1946	81,250 Kva 3,600 rpm hydrogen cooled	98.7

There has been no significant change in the standard dielectric tests for stator and field windings of generators throughout this period. The standards were revised otherwise in 1922, 1925, 1927, 1936 and 1943.

The standard temperature rise for stator windings with Class B insulation was increased from 60 C to 80 C in 1925 for large turbo and hydro-generators and remains unchanged.

Field windings with Class B insulation were permitted 55 C rise until 1925, when this was increased to 90 C for turbo generators and 80 C for hydro generators. These values are still in effect.

Though there was a period about 1920 when 110 C rise windings were used in some machines, it was found that winding insulation would have a short life at this temperature, and today manufacturers design for not more than 60 C rise in stator windings and for 85 C rise or less in turbo generator field windings. Stator winding temperature is determined by use of resistance temperature detectors. Field winding resistance is used to determine its temperature.

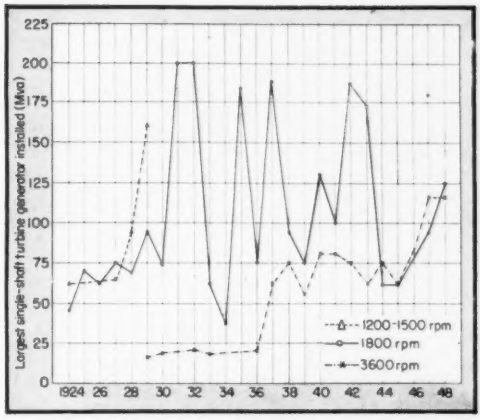

FIG 3—U. S. TREND in maximum turbogenerator capacity at three speeds. Ratings of 3,600-rpm units have risen steadily

FIG 4—FIELD WINDING end-turns of turbogenerator distorted due to temperature changes with generator under speed

Standard Ratings

Looking forward to the time when generator production for power plants would be fully resumed, a joint committee of the AIEE and ASME prepared

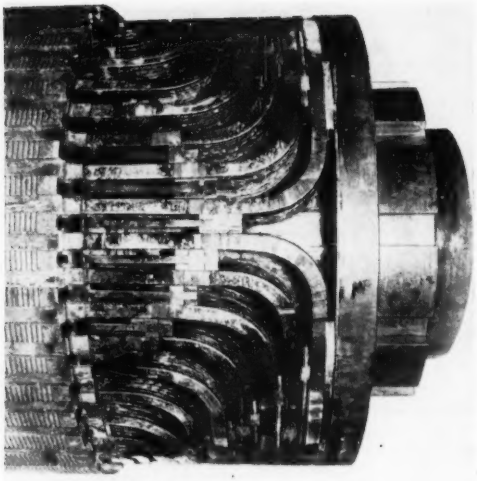

FIG 5—LATEST DESIGN of turbogenerator field-winding end-turn construction uses cold-worked copper alloys

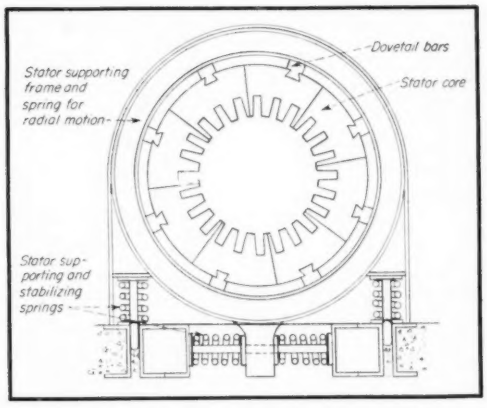
Dovetail bars
Stator core
Stator supporting frame and spring for radial motion
Stator supporting and stabilizing springs

FIG 6—SCHEMATIC DIAGRAM of spring supports for 3600-rpm turbogenerator stator to overcome vibration difficulties

"Standard Ratings for Large 3,600-rpm Three-Phase, 60-cycle Condensing Steam Turbine Generators." This standard, approved in 1945, covered air-cooled generator ratings of 11,500 and 15,000 kw; and hydrogen cooled ratings of 20,000, 30,000, 40,000, and 60,000 kw. Due to simplification of the hydrogen system, the 15,000 kw machine has recently been included in the hydrogen cooled list. These standards include stator voltages of 11.5, 12.5, 13.8, or 14.4 kv; power factor 0.85; and short circuit ratio 0.80. Recent orders have indicated a reasonably good acceptance of these standard ratings. They represent 20% of the 1948 deliveries, 30% of the expected 1949 deliveries, and 40% of the anticipated 1950 deliveries.

Shown in Fig 7 is the total installed generator capacity in the United States for each of the last twenty-five years and Fig 8 gives the accumulated total kw of generating capacity available in this country.

Outdoor Installations

To lower installation cost, the first outdoor turbine generator set was installed in 1932. The machine was small, rated 6,000 kw, but its performance has inspired the installation of a number of outdoor units throughout the country, particularly in the more favorable weather areas. The first hydrogen cooled outdoor turbo generator was shipped in 1940. It was rated 20,000 kw, 3,600 rpm, 13.8 kv. By 1947, operators in the Southwest were installing outdoor generators as large as 60,000 kw.

Hydrogen-cooled generators require bushing terminals. This lends itself admirably to the use of isolated phase metal clad bus construction from the generator bushings directly into the station switching galleries, or to other terminal equipment such as "step-up" transformers (Fig 9).

Shown in Fig 10 is a modern installation of 3,600 rpm, hydrogen cooled turbine generator.

European Highlights

The first 30,000-v generators were built and operated in Italy in 1905. There were two machines, each rated 5,200 kva. In 1928 the first modern 33,000-v machine was manufactured in England and placed in service at Brimsdown Station. The machine was rated 25,000 kw. The armature bar design consists of three concentric conductors. The center conductor operates up to 33 kv, the intermediate conductor operates up to 22 kv and the outer conductor operates up to 11 kv. This design impresses no more than 11 kv on any single element of the insulation.

Some difficulties have been experienced with the end connections of this type of bar. However, these problems are reported to have been solved.

In all, 21 generators rated 33 to 36 kv are reported to be in service and 13 others are under construction. They vary in size from 24,000 to 62,500 kva, and are located in England, South Africa, India and on the Continent.

European development of field rotors has progressed much along the same lines as in this country. However, one design, used relatively little outside of Germany, has a full length forging of small diameter with dovetail slots for installation of punchings. The punchings are pre-shaped to form the rotor slots and are held together by clamping rings and through-bolts.

Hydro Generator Development

In 1924 considerable progress had already been attained in design and construction of hydro generators. The largest machines operating at that time were the 65,000-kva, 12,000 v, 107-rpm, 25-cycle generators for one of the Niagara Falls stations. The then current design included cast rotor spiders, cast stator frames, open type ventilation and no amortisseur winding. In locations where higher heads of water were available,

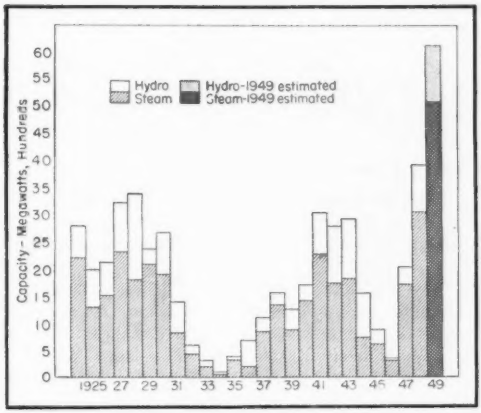

FIG 7—STEAM TURBINE and hydrogenerator installations in the United States shown for the period during 1924-1949

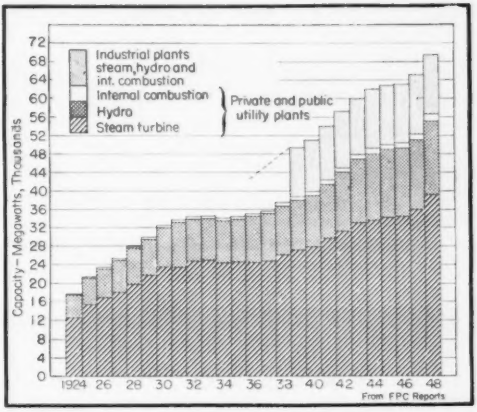

FIG 8—INSTALLED electric generating capacity in the U. S. Industrial plants are shown independently of utility plants

Pelton wheels were used to drive horizontally mounted generators as large as 22,223 kva at 171 rpm.

The first of the 65,000-kva Niagara Falls machines was installed in 1923 and others followed in 1924. They were designed for low excitation and windage losses. Stranded conductors were used in the stator winding and the winding was equipped with resistance type temperature detectors. The Kingsbury thrust bearings supported a total thrust bearing load of 1,250,000 lb. These machines were the first among both the steam turbine and hydro driven generators to have auxiliary a-c generators directly connected to the main shaft.

Construction Improvements

Though used on small machines about 1924, as early as 1927, steel plate frame construction was beginning to take the place of cast sections in large machines, to provide a stronger structure to reduce generator weight and assist with shipping difficulties. Machines of large physical size, though lower kva ratings than the Niagara Falls unit, were built for low head, low speed operation at Conowingo. In physical size and weight these 40,000-kva, 81.8-rpm units were the largest built so far. Propeller type water wheels with adjustable blades were developed to permit operation of generators at higher speeds on low head installations. This results in smaller and more economical machines.

One of the most important developments in hydro generators has been the "overhung" rotor design (Fig 11). The thrust bearing is located below the generator rotor and is generally combined with a guide bearing at the same location. In some machines a guide bearing is also used above the rotor. This construction avoids the heavy bracket extending over the stator for support of the thrust bearing and the rotating parts of the machine. Where a single guide bearing is used this design does not permit operation as a synchronous condenser unless means are provided for operating the water wheel for this condition. Also, it does not permit operation of the generator alone to permit measurement of mechanical losses.

The overhung design is sometimes referred to as the "umbrella" rotor. However, the true and original "umbrella" design has the stator completely inside of the revolving rotor. The field poles face toward the center of the machine while the stator core surfaces face outward. Units of this type were installed at Niagara Falls as early as 1895.

In the United States practically all vertical water wheel generator thrust bearings are either Kingsbury or spring types. The largest bearings now carry a total thrust and rotor load of approximately 3,000,000 lb. Though some cases exist where guide bearings are located both above and below the rotor most generators of the overhung design have no guide bearing above the generator rotor.

Stator Core Construction

The improvements in the design of stator cores parallel those of the steam turbo generator. Some early difficulties with slippage of the core in vertical shaft machines were overcome by design improvements which provided for secure positioning of the core laminations.

Hydro generator voltages vary from 2,400 to 13,800 v generally, though machines have been built for 16,500 and 22,000 v.

Recent designs were directed toward generators that would supply large values of line charging current and have high electrical stability. This need has been met by designing machines with large air gaps resulting in high short circuit ratio. Amortisseur windings have been included in modern designs for the purpose of increasing electrical stability and also to reduce transient voltages associated with abnormal line conditions. These windings produce damping action which reduces the electro-mechanical oscillations of the rotors during and immediately following an electrical system disturbance. Hydro generators can readily be adapted to special cases of service, for example, two large verti-

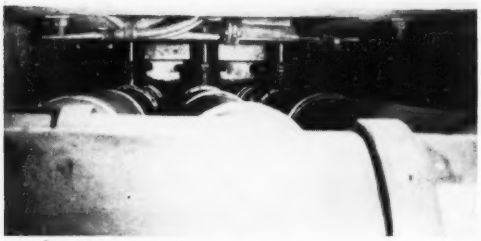

FIG 9—METAL-CLAD generator leads connecting to a 50,000-kw hydrogen-cooled turbogenerator in modern installation

FIG 10—1946 INSTALLATION of 81,250-kva, 3600-rpm hydrogen-cooled turbogenerator in a generating station

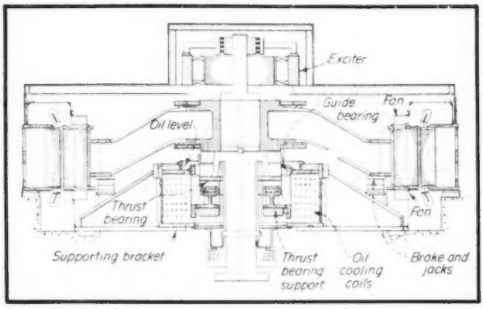

FIG 11—OVERHUNG TYPE hydrogenerator cross section

cal type generators were built some years ago for single phase power supply to help electrify a railroad system. These machines, rated 35,000 kva, 100 rpm have heavy rotor amortisseur windings and have their stator frames spring mounted to isolate the pulsating torque of the load.

Generator Windings

The design of stator and field insulation for hydro generators also followed much the same pattern as that described for turbo generators. Though Class "A" materials were in use for stator windings in 1924, class "B" materials are used throughout in present day designs.

Stator winding life has been increased by the change from open to closed ventilating systems, using air coolers and fans on the rotor. The closed cooling system prevents the collection of dirt in the windings and cooling air ducts, resulting in more uniformly low temperature throughout the machine.

The stator coils are coated with a conducting material over the slot portion to reduce the effects of corona. The same procedure is followed for steam-turbine-driven machines.

Design Characteristics

The efficiency of large hydro generators vary from 97 to 98.5% at the present time.

Material strengths, speeds and manufacturing facilities are the usual limitations faced by the designers of large hydro generators. At 1,000 rpm generator size is limited to approximately 7,000 kva. At 400 rpm, 60,000 kva can be constructed and at 200 rpm the limit is approximately 100,000 kva. The largest machines in term of kva rating are capable of 108,000 kva at 120 rpm.

The highest head reaction unit installation in the United States is 920-ft high. Impulse wheel heads exceed 2,400 ft.

Possible Future Trends

It may reasonably be expected that further improvements in material qualities will appear to aid the designer of electric generators. The maximum kva rating, particularly of 3,600 rpm steam turbine generators, may be expected to increase. It is reasonable also to expect that the magnetic qualities of stator core iron will be improved with resulting lower core losses.

It is expected that the acceptance of standard ratings for 3,600 rpm turbo generators will increase above the 40% acceptance for 1950.

Further simplification of the hydrogen control system for turbine generators is expected to make its appearance soon. More general use of high pressure hydrogen cooling (up to 30 psi) may be expected. Two new methods of generator cooling, namely; (A) Liquid cooling and (B) water vapor cooling, have been proposed recently. Further attention may be expected on these suggestions, though no general change to these types of cooling are expected soon.

Improvements in insulating materials may be expected for all types of generators. Further uses of plastics and possibly the adoption of Silicone materials may improve the dielectric characteristics and the life of stator and field winding insulation. Higher stator voltages may become practical but there seems to be no economic advantage to be obtained from their application for such purposes, at present.

It is possible that the generator excitation voltages for turbine driven machines may be increased from the present standard 250 v to a voltage between 375 and 500 v. This will reduce the current which must be handled by the exciter and the collector rings.

Further improvements in the physical properties of field winding materials may be expected since much attention is being given to this subject. Also it is possible that developments will be forthcoming in stranding methods used in the manufacture of stator winding bars.

Station Bus Patterns

Complex bus schemes of the mid-twenties superseded by progressive simplification. Movement toward outdoor installation and phase isolation Trend toward more bus sectionalization and system-wide coordination

TWENTY-FIVE YEARS AGO station bus schemes were practically at the peak of complexity and use of a wide variety of basic schemes and variations of these schemes. Many of these schemes involved much duplication of equipment and were intended to guard completely against interrupting any circuit in case of failure of any circuit breaker or other equipment.

This duplication of equipment was the result of previous experience with failures of circuit breakers and the increasing demand for continuous service. However, it did not prove to be a complete solution because circuit breaker failures were relatively common and were all too frequently accompanied by fire with consequent property damage and personal injury. Efforts to minimize the seriousness of these failures soon resulted in a trend towards outdoor switching structures to provide greater spacing and improved access for fire fighting.

Simplification Started

During the ensuing 25 years there has been a definite trend towards simpler bus schemes, resulting from: (1) The development of more reliable switching equipment and (2) circuit breakers with higher interrupting capacity. Meanwhile the increasing cost of circuit breakers for higher interrupting duty has forced more careful consideration of the need for duplication of switching facilities.

Another factor, possibly even more important, is better coordination between the bus scheme and the rest of the system design. It is quite obvious that there is no need of providing duplicate facilities in a switching structure if the system design is such that an interruption of an individual circuit does not interfere with service.

Schemes Classified

It may be well to consider the progress in station bus patterns in two rather distinct parts—

(1) The basic diagram of connections or scheme of operation; (2) the type of construction or physical arrangement.

Considering first the basic diagram or scheme of operation, we find that practically all of the station bus schemes which have evolved may be divided into a limited number of major classifications, each of which is subject to numerous variations and combinations. Some of these major classifications are:

(1) single bus; (2) main and transfer bus; (3) double bus, single breaker; (4) double bus, double breaker; (5) ring bus; and (6) synchronizing bus.

Single Bus Scheme

The "single bus" scheme (Fig 1) is the oldest and simplest of all bus schemes. It was used in the earliest installations because of its simplicity. As the demand for continuous service developed it became necessary to make provision for failures and other outages of circuit breakers and other switching equipment without interrupting service. This led to the development of various double bus and ring bus schemes with numerous variations, such as the "H" scheme, the "Group Bus" scheme, and the probable ultimate in flexibility, sometimes referred to as the "Essex Waffle."

The single bus scheme is still used in many applications including some of the most modern installations. There are some situations, particularly in industrial plants, where interruptions of individual circuits can be tolerated, and in such situations the single bus scheme is quite generally accepted. In many electric utility distribution systems, emergency ties between circuits in the field or interconnection of circuits, as in the primary network, make adequate provision for outages of the circuit breakers or even an entire substation without interrupting service, and in these situations the single bus scheme is quite generally used.

There has been a rather definite trend toward sectionalizing in order to limit the extent of outages and to provide backup protection by de-energizing a section of bus if the breaker on any circuit fails to clear.

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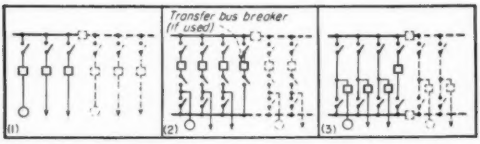

FIG 1–SINGLE BUS. FIG 2–MAIN and Transfer Bus
FIG 3–DOUBLE BUS, single breaker

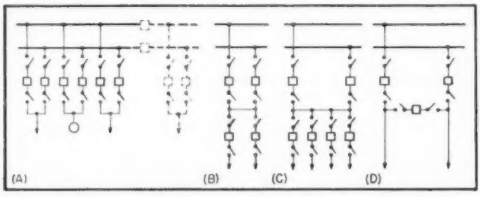

FIG 4–DOUBLE BUS, DOUBLE BREAKER. Backup protection is provided by (B) and (C) in case of failure of an individual feeder breaker but they do not provide for an outage of an individual feeder breaker without interrupting the feeder involved

Main and Transfer

The "main and transfer" bus scheme (Fig 2) is one of the most economical methods of providing for outages for maintenance of circuit breakers without interrupting the circuit involved and without resorting to switching outside of the station. This scheme is often used with an extra circuit breaker to carry any individual circuit through the transfer bus while the breaker on the individual circuit is out of service. There are also numerous installations of the main and transfer bus without the extra breaker, in which case any circuit can be carried through the transfer bus along with any other circuit while its own breaker is out of service for maintenance.

This scheme is widely used in high tension switching stations and in distribution stations where it is considered desirable to provide for outages on the individual circuit breakers without requiring switching outside of the station.

Double Bus, Single Breaker

The "double bus, single breaker" scheme (Fig 3) was developed to provide for shifting individual circuits from one source to another and to provide for an outage of either bus without interrupting service. It does not provide for an outage of any individual circuit breaker without interrupting the circuit involved. It is still used to a limited extent in situations where the system is normally operated in two parts and where it is necessary to shift individual circuits from one part of the system to the other. In such cases either bus can be taken out of service by temporarily connecting all of the circuits to the other bus.

Double Bus, Double Breaker

The "double bus, double breaker" scheme (Fig 4A) came into quite general use as systems grew and as the demand for continuous service increased. It provides for an outage of any individual circuit breaker, or an outage of either bus without interrupting any individual circuit. There are still some situations where its use seems to be justified, but with the higher interrupting duty and consequent higher cost of circuit breakers, it has become too expensive for general application.

The so-called "H" scheme (Fig 4B) may be considered as a variation of the basic double bus scheme. In this case two circuits are supplied from one or the other of the main buses through one of the main breakers, and each circuit has another individual breaker. This scheme provides backup protection in case of a failure of the individual circuit breaker to open, but it does not provide for maintenance of the individual circuit breaker without an interruption of service.

Group and 1½-Breaker Schemes

Another scheme, sometimes called the "Group Bus" Scheme (Fig 4C), may also be considered as a variation of the basic double bus scheme. This scheme is similar to the "H" Scheme except that more than two circuits are supplied by one pair of main breakers. It has the same advantages and the same disadvantages as the "H" Scheme.

Still another scheme, sometimes called the "1½ Breaker" Scheme (Fig 4D) may also be considered as a variation of the basic double bus scheme. In this case, two circuits are supplied by three breakers (1½ breakers per circuit) as shown in (Fig 4D). This scheme provides for maintenance of any breaker without interrupting any circuit. It has had rather limited application, principally for high voltages.

Synchronizing Bus

The "synchronizing bus" or star scheme (Fig 5) has been used principally in generating stations, with reactors in the connections between the unit bus sections and the synchronizing bus. Its principal advantage is the limitation of fault current magnitude without requiring all of the load to flow through reactors. This scheme is found in several variations–sometimes with tie breakers between the unit bus sections and sometimes with various arrangements of selector breakers, etc. The unit bus sections are often found in the single bus arrangement and sometimes in one or the other of the multiple bus arrangements. This scheme seems to have a definite field of application, particularly in urban systems, where a large part of the load is delivered at generator voltage. However, with the trend toward stepping up the entire output of generators to higher voltages, it will probably find less application in the future than in the past.

Ring Bus

The "ring bus" scheme (Fig 6) appears in two quite different fields of application. It has been used in moderate voltage applications, as in Fig 6 (left). Its principal advantage is that it provides for connection between the remaining bus sections when any one bus section is out of service. It is sometimes used with one or the other of the multiple bus schemes in each

section. This same basic scheme is often used in high voltage applications, usually with one circuit on each section, as in Fig 6 (right). This scheme provides for maintenance of any circuit breaker without interrupting any circuit and without any transfer bus or additional breakers.

An interesting scheme which attained considerable popularity a few years ago involved the use of double winding generators, with each of the windings connected to different sections of the bus.

Phase Isolation

Considering next the type of construction or physical arrangement of the equipment, we find that 25 years ago most of the indoor bus structures consisted of masonry cells of one form or another. This was the result of experience with the older open type structures, and was developed in an effort to prevent the spread of trouble in the structure.

One of the interesting schemes developed to limit the extent of damage, involved isolating the phases or locating each phase in a separate room or on a separate floor of the switchhouse. This was done to guard against the possibility of phase-to-phase faults and to insure that any faults which did occur would be from one phase to ground, where the magnitude of the fault current could be limited by resistance in the neutral ground connection. Two common patterns were developed, the vertical-phase isolation and the horizontal-phase isolation arrangements. In either case, all electrical equipment of each phase was located in a separate room, and masonry compartments were generally used to house the equipment. This isolated-phase arrangement greatly reduced the possibility of phase-to-phase faults and provided for limitation of the magnitude of faults from phase to ground on systems where resistance could be used in the neutral ground connection. However, it proved to be quite expensive and its use has been almost completely discontinued.

Barriers and Enclosures

In recent years there has been a rather definite trend away from masonry cell construction to metal enclosed structures with the phases adjacent. These have been developed in two different forms, one the so-called segregated-phase arrangement with a single metal barrier between phases and the other the so-called isolated-phase arrangement with each phase in a separate metal housing with air space between the individual housings. There has also been a rather definite trend toward factory-built metal-enclosed switch structures and many of these are being installed outdoors, particularly in low and moderate voltage classes. Most of the higher voltage outdoor structures still use open construction with individual outdoor circuit breakers and other equipment.

Another interesting development during the past 25 years is the practice regarding generator leads. Twenty five years ago most of the generators were rather small by comparison with present day machines and it was quite general practice to use cable for the leads from the

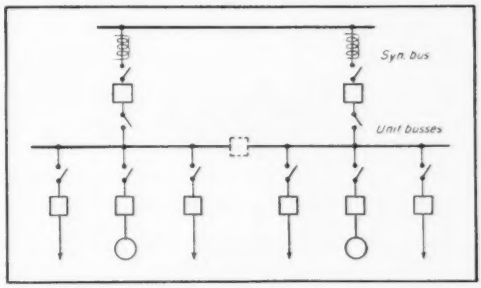

FIG 5–SYNCHRONIZING BUS

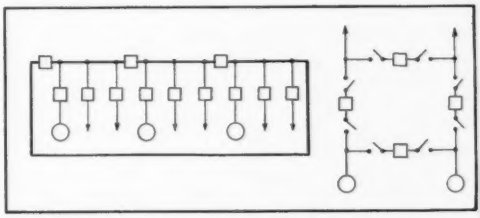

FIG 6–RING BUS in two patterns. Scheme at left is for low-voltage applications, at right for high-voltage applications

generator to the switching structure or transformers. As the size of generators increased, multiple cables were used, and still are in some cases, though there has been a rather general trend towards the use of bus construction instead of multiple cables for the larger generators.

Prevailing Trends

There is a rather definite trend towards simpler bus schemes, requiring less equipment. This is partly due to the development of more reliable equipment and circuit breakers with adequate interrupting capacity and partly to the increasing use of bulk-power transmission at higher voltages to load-area substations, even in some of the metropolitan systems. This permits the complete elimination of the low tension bus system at the generating station.

There is a very definite trend toward more sectionalization and the use of smaller bus sections in practically all of the installations made recently. This permits an outage of any bus section with a minimum of interference with normal operation. It also provides opportunities for backup protection by de-energizing a section of bus in case of breaker failure on an individual circuit.

There are very encouraging signs of a definite trend towards more complete coordination between the station bus scheme and the rest of the system design. It is coming to be quite generally recognized that if the general system design is such that individual circuits can be taken out of service, it is not necessary to provide duplicate equipment in a switching structure in order to continue service to an individual circuit while its breaker is out of service. One of the greatest opportunities for improvement in the future lies in careful coordination between the station bus patterns and the rest of the system design.

Progress in Power Switchgear

Committees on technological development of NEMA assist in tracing the advancements in circuit breakers, power switching devices and switchgear assemblies

THE ENGINEER'S ABILITY to control the vast systems of generation and distribution is in large part due to the constant and pointed development of the vital basic switching groups—Power Circuit Breakers, Air Circuit Breakers, Power Switching Devices, and Power Switchgear Assemblies.

That sound growth was had through this twenty-five year period is remarkable. It had its beginning in the wild expansion of the middle 20's, suffered the curtailments of the depression, met the requirements of a mechanized war and then faced the changed technological need in an immediate postwar expansion of quantity and kind for industrials and utilities which surpassed anything in the history of the business.

Power Circuit Breakers

Twenty-five years ago an oil circuit breaker was considered acceptable provided it interrupted its maximum short-circuit current without extreme distress. The spilling of oil and the emission of gases from the tanks were considered to be inevitable. Predetermination of the breaker's interrupting capabilities involving consideration of the complex transient conditions in the breaker arc as well as the entire system had not been achieved. The design of breakers was therefore more of an art than a science.

Realizing the deficiencies of the breakers available twenty-five years ago, manufacturers, by investigations in their laboratories and then field testing in cooperation with utilities, determined that the solution to the problem of adequate designs lay in the direction of reducing arc energy. This was accomplished by enclosing or partially enclosing the arc in a small, extremely strong secondary enclosure. Thus the tank pressure was reduced to reasonable limits, interrupting ability was increased, and there was less deterioration of the oil and general maintenance. So far as interrupting ability was concerned, this resulted in a generally satisfactory performance for a short time, but the growth of systems brought forth the need of greater stability through faster breakers, and many industrial processes required a duty cycle with less than a two-minute interval between interruptions then considered standard.

Interrupting Ability

This required additional and more elaborate studies in the laboratory and field of interrupting ability and resulted in greatly improved arc control methods which in turn resulted in complete redesign of mechanisms and tanks for greater speed, strength, and greatly reduced oil volume, and of bushing-type current transformers for greater accuracy and volt-ampere burden. This resulted in reliable application data and the constant reduction of interrupting time from 12 cycles to 8 to 5 and 3 cycles, depending on the kva size and voltage. The duty cycle was reduced to a 15-sec interval. This was a marked improvement but still not good enough to keep step with stability requirements or prevent restarting of motors and damage to industrial processes. Further study by the manufacturers resulted in instantaneous reclosing times of 35, 30 and finally 20 cycles for super-high-speed reclosing.

Springing from the same problems or as a consequence of individual improvement, other needs were met in the way of practically elminating contact oxidation and arc erosion by the use of silver and tungsten. The bushing has longer life, meets impulse test requirements, provides greater corona control and can be provided with potential taps to eliminate high voltage potential transformers where desirable. The pneumatic operator made possible fast closing of large breakers, especially at distances otherwise resulting in excessive drop of d-c control voltage. The mechanical strength requirements have been met by use of welded structures, and collectively this has reduced the weight and size of most breakers with consequent less cost of installation and operation.

While the foregoing had produced an excellent oil circuit breaker, much attention has been given since 1936 to the elimination of oil, particularly for indoor

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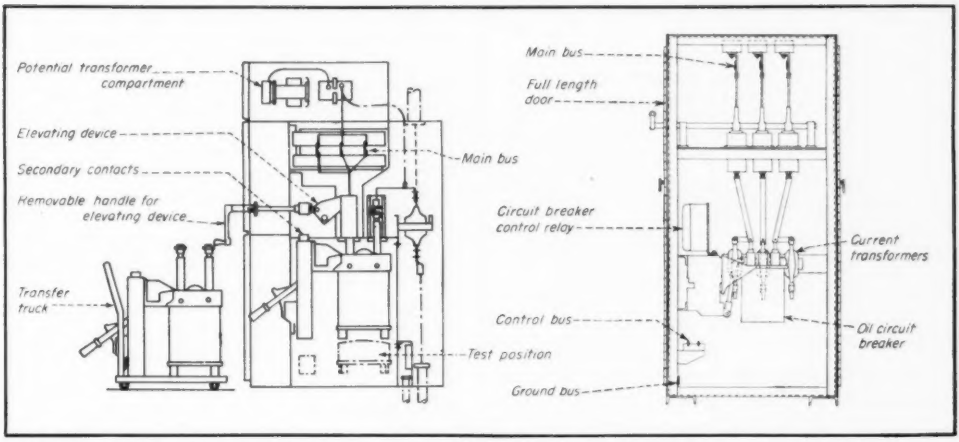

FIG 1—METAL-CLAD SWITCHGEAR (left) with vertical-lift circuit breaker. Fig 2—Indoor metal-clad cubicle (right)

applications in the belief that such would tend to less maintenance and certainly eliminate the fire hazard. The indoor development offered the most advantageous field and two forms of oilless circuit breakers were provided for requirements where oil circuit breakers had been used before—the magnetic breakers for voltages up to 15 kv and 500,000 kva, and air-blast breakers from 500,000 kva to 2,500,000 kva and 15 kv to 34.5 kv.

Air-blast breakers for outdoor service at 15, 34.5 and 69 kv put into experimental use in cooperation with the users have demonstrated that, at least in the 15-kv class, there are real advantages and some installations are now on order.

Coordinated Program

A very effective element in the foregoing development is the work throughout this period of two user-manufacturer coordinating committees—the AEIC Committee on Switching and Switchgear and the EEI-AEIC-NEMA Joint Committee on Power Circuit Breakers. They have brought to light many technical and economic needs of the industry for the guidance of design and application engineers.

The accomplishment, started in 1931-32 with the Schedule of Preferred Ratings, reduced the number of outdoor and indoor breaker ratings by 27 and 35%, respectively, and the 1949 revision (ASA Standard C37.6) contains 35% fewer ratings than the last schedule of 1945. The demand for increased interrupting capacity in the high-voltage breakers is indicated by the fact that since approval of the 1949 revision, which is not yet officially issued, requirements have developed for ratings above the 5 million listed for the 138 to 230-kv class. For the 138 to 161-kv breakers, 6 and 7½ million are being considered and contracts have been let for 7½ and 10 million for 230 kv. For higher voltage ratings of 287 and 360-kv, which as an operating system is now under experimental field investigation, a 360-kv, 10-million kva breaker has been developed.

Testing Clarified

The veil of mystery that clothed factory testing was clarified by a complete report on oil circuit breaker testing. It included an effective presentation on the effect of rate of rise of recovery voltage, eventually leading to an understanding of its effect on circuit breaker design.

An accurate method of reporting circuit breaker performance, good or bad, effected great reduction of mechanical and electrical defects, eliminated the great number of special details, caused the reorganizing of both manufacturer and user's inspection systems, and improved designs and introduced new materials and production methods.

To fill the need of an understanding of the basic or fundamental requirements, there was issued a "Specification for Oil Circuit Breakers" designed to be used as purchaser's specification or as a reference by him and the manufacturer. "Recommended Future Development in Oil Circuit Breakers" was issued the same year covering desirable changes or developments. It is expected that a much needed "Schedule of Rating Factors for Reclosing Service" will be available in the near future.

Air Circuit Breakers

Air circuit breakers are and have been the chief protective and switching device for electric power systems of 600 v and below to take the place of the fused switch which was deficient in interrupting ability and which required frequent fuse replacements with the consequent long shutdowns for this purpose.

Twenty-five years ago they consisted generally of spring copper laminated contacts with carbon blocks for arcing contacts, and their modest success could be attributed to the relatively low values of short-circuit current which were available in the low voltage systems of the time.

Whereas early air circuit breakers were nearly all

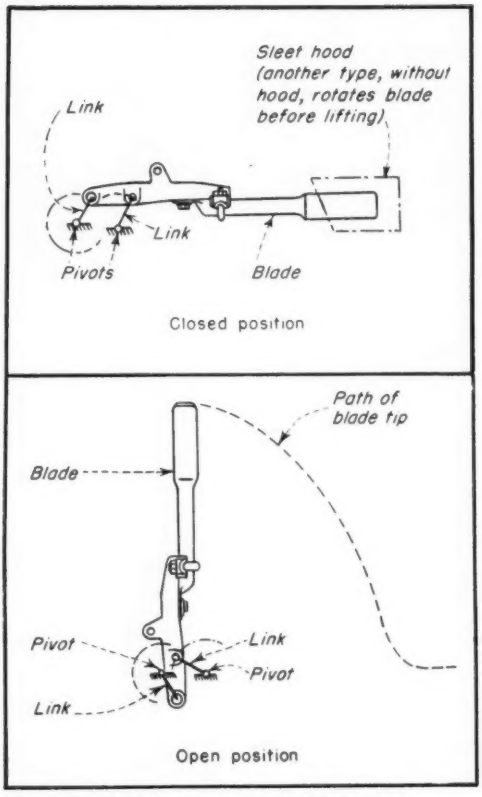

FIG 3—DIAGRAM of non-icing air-break switches

single pole, non-trip-free for use on two-wire d-c circuits they were adapted some twenty-five years ago to polyphase a-c service by the introduction, as the industry standard, of the three-pole "free-handle" or "trip-free" breaker.

The individually enclosed air circuit breaker was next introduced to meet the need for a higher interruption-rated switch than the fused type A switch.

Interrupting Ratings

In 1931 the first interrupting current ratings were published for listed standard circuit breakers; previously special breakers were developed with specific interruption capacities. There was considerable activity by the industry in testing the interrupting capacity of circuit breakers. The development was directed largely to improving the performance of the circuit breakers in each interrupting size.

The carbon tip was replaced with metal alloys better adapted to withstand arcing and solid block silver surfaced main contacts were used to prevent oxidation and deterioration. Breaker mechanisms were built for higher speeds of operation and contacts improved to withstand the higher currents of expanding distribution systems.

With the introduction of the totally-enclosed metal-clad switchgear, the draw-out circuit breaker came into use. This switchgear with its removable and interchangeable breakers and its many advantages of safety, reliability and space economy has become an industry standard for all high-grade installations.

Circuit breakers with various types of tripping characteristics were developed and standardized to meet specific service requirements. These were instantaneous-magnetic, dual-magnetic, thermal-magnetic, selective or sequential-magnetic and non-adjustable thermal breakers. The magnetic types are generally used for the protection of generators, motors, and large feeders. Thermal breakers were developed as low price, non-tamperable overload devices for use in lighting panelboards and for low interrupting capacity motor and power circuits.

Power Switching Devices

Power switching devices provide the means for isolating equipment such as circuit breakers and transformers from buses and for supporting and insulating buses in generating stations and substations. Originally the installations were entirely indoors but with the rise of transmission voltages the outdoor substation became an economic necessity so that during the past twenty-five years outdoor installations have become firmly established.

Porcelain insulators for outdoor stations were a gradual development from ordinary line type insulators with threaded pinhole and tie wire grooves to the present high-strength insulator with metal caps for the attachment of fixtures. The development of the sanded-head switch insulator with malleable iron caps and cementing compounds that absorbed temperature stresses resulted in the present satisfactory line of outdoor switch insulators. These have been standardized in dimensions and electrical and mechanical characteristics for each voltage rating known as the "Basic Insulation Levels."

Post Insulator

Post-type insulators for indoor use were placed on the market. The first standardized unit consisted of skirted porcelain insulators with malleable iron thimbles at each end having holes tapped to take standard conductor and base fittings. Since the bottom and top of the post insulator castings were identical, insulators could be stacked for higher voltages and any type of standard fitting used at either end. They have therefore been used extensively for disconnecting switches, fuse mountings and bus supports. To meet demands for greater mechanical strength, other types of standardized indoor units have since been developed.

The group-operated air-break switch was developed to meet the need of safe, positive, and remote switch operation for isolating and sectionalizing lines and equipment. It must operate unfailingly under all kinds of weather conditions even though it may have remained closed or open for months previous. In an endeavor to insure positive switch operation under all conditions, manufacturers introduced several types of

operating mechanisms such as the rocker type and the rotating insulator type, the vertical break and the horizontal single and double break switches.

Shaft bearings were changed from the ordinary greased sleeve type, which often "froze", to the greaseless ball or roller-type bearing which permitted free movement under all weather conditions.

Switch contacts were also developed from the simple clip-type wiping contact to the double self-aligning-full-floating pressure types. Switches up to 6,000 amp with this type of contact are now in general use.

The corrosion of metal non-current-carrying parts of switches was overcome by the introduction of high tensile strength bronze fittings above the insulators and silicone-bronze bolts and nuts. This insured easier operation and longer life with less maintenance.

Disconnecting Switch

Disconnecting switches are now built in ratings up to 287,000 v; however, they are still used only as an isolating device capable of interrupting only moderate loads or charging currents in an emergency. The demand for load-break, high-voltage air switches has stimulated the development of this switch. Devices of this type for lower voltage ratings are already on the market and will no doubt be followed by those of higher voltage as operating experience and the manufacturers' know-how is applied to the problem.

As with other types of switching apparatus, outdoor power switching equipment now has been well standardized as to types, voltage ratings, insulation, continuous and short-time current ratings.

Coincident with the improvement of air break switches there has been a steady development in the auxiliary operating devices, such as manual and motor-operated controls, automatic throwover and sectionalizing equipment and safety interlocking of switches.

The indoor disconnecting switch has similarly kept pace with the improvements in the design of the outdoor switch. Contacts have been improved by the use of silver surfaces and high pressures to meet the demand of greater current-carrying capacities. Switch construction has been made more sturdy to enable it to withstand the mechanical stresses of high short-circuit currents and to coordinate it with the momentary ratings of the oil and air-blast breakers. Switch sizes have been standardized so that there are current and voltage ratings available for any standard service.

Bus support fittings, bus and cable fittings have been steadily improved by using high strength bronze, silicone-bronze bolt material with amply designed pressure contacts.

Power Fuses

High-voltage fuses have progressed in their development from the fusible wire expulsion fuse to the more reliable liquid-filled and boric-acid, dry-type fuses. These later fuses have been developed for ratings up to 138,000 v and 1,000,000 kva. Current-limiting dry-type fuses were developed with interruption ratings as high as 130,000 amp at certain voltages.

The development of the current-limiting fuse with its high speed, definite time characteristics gave added protection to major station equipment by actually limiting the fault current to a time often as little as a one-half cycle.

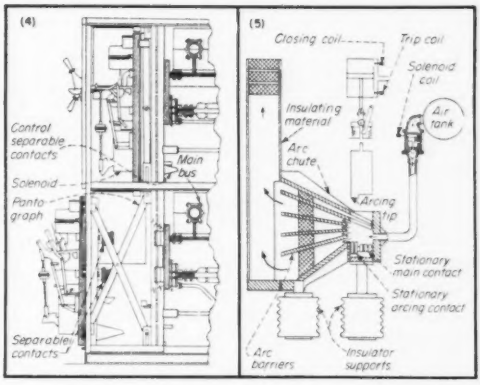

FIG 4—DRAW-OUT air circuit breaker, metal-clad switchgear
FIG 5—SCHEMATIC DIAGRAM of air-blast circuit breaker

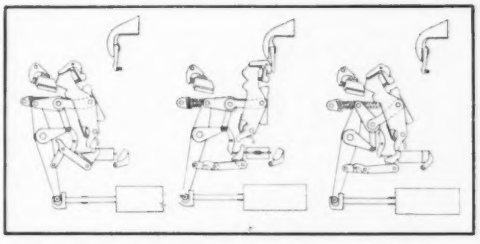

FIG 6—PRINCIPLE of trip-free action of air circuit breaker. (Left) breaker open, trip coil and closing coil not energized; (center) breaker closed, closing coil energized but trip coil not energized; (right) trip-free operation, both coils energized

Power Switchgear Assemblies

Coincident with the introduction of the oil circuit breaker, switchboards were built to utilize this power controlling equipment. They consisted generally of vertical panels on which instruments, relays, and sometimes the circuit breakers were mounted. Buses and electrical connections were often exposed making them fire hazards and vulnerable to communicating equipment faults to adjacent circuits. These component parts were usually bought as separate items by the user. He planned and executed their assembly into complete functional units, or at best bought assemblies from manufacturers built to his specification.

Concrete Cell Structures

Later, primary power switching equipment, that is, circuit breakers, disconnecting switches, and buses were installed in concrete cell structures that were usually designed and built by the owner. This practice reduced the hazards of equipment failures and isolated system failures.

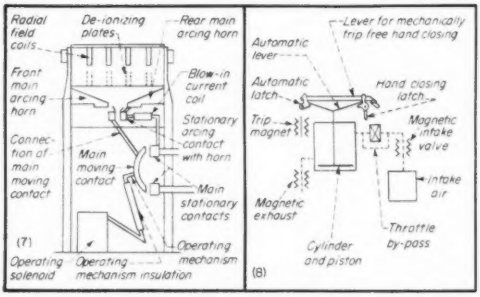

FIG 7–SCHEMATIC diagram of de-ionization breaker
FIG 8–SCHEMATIC diagram of pneumatic-operated breaker

Cubicle Units

In the middle 20's–the beginning of this twenty-five year period–the indoor metal switchgear cubicle units were developed to compete with the concrete bus and switch compartments. They contained main buses and disconnecting switches in addition to the oil circuit breaker. The expected advantages were that it would cost less, provide better isolation, protection against foreign objects, and greater service continuity.

The first metal-clad switchgear manufactured in the United States was compound-filled and provided the first draw-out designs of metal-enclosed switchgear. It was later changed to oil-filled compartments, and then to semi-fluid petrolatum filled.

In 1928 the modern metal-clad switchgear was initiated. It differed from the cubicle type and its predecessor the "Removable Truck Switchgear" in that only the circuit breakers were removable and the compartments were not liquid filled. The stationary structure contained buses with phenolic insulation, current and potential transformers, controls, and instruments. This design included horizontal draw-out and vertical lift-type circuit breakers for 15-kv and 500,000-kva circuit interrupting capacities and below.

This type of switchgear because of its easily removable and replaceable circuit breakers has effected economies by replacing multiple with single bus systems while still providing reliable and continuous service.

Oilless-type circuit breakers in metal-clad switchgear was a later development that eliminated the fire hazard incident to the use of oil.

Metal-clad Equipment

Indoor metal-clad switchgear development also profited by the coordinating activities of the AEIC committee on Switching and Switchgear and the EEI-AEIC-NEMA Joint Committee on Power Circuit Breakers. They have recently produced a Guide for Specification on Indoor Metal-Clad Switchgear.

About 1930 the installation of low-voltage air circuit breakers in metal-enclosed switchgear began, first in the stationary and later in the draw-out type. This later type conserved space by replacing disconnecting switches with disconnecting contacts similar to those used in the higher voltage switchgear.

The "unit substation" was next to come into general use. It combined the power transformer and the metal-clad switchgear into a completely engineered and factory-built compact unit that reduced field installation and assembly. These units provided economical usage for load center distribution both for network and radial feeder systems; also for indoor, outdoor, and underground vault installations.

In 1935 the metal-enclosed safety-type switchgear was developed for large generating stations and substations and consisted of cubicle units housing large station-type circuit breakers with their isolating switches, instrument transformers, and control relays.

Control Boards

Control and instrument switchboards followed the trend of power switchgear. The open panel, field assembled and wired switchboard has been practically replaced by the new metal-enclosed, single and duplex complete factory assembled and wired switchboard. Again the ease of installation, economy of space, safety, convenience, and pleasing appearance were the factors that brought about the change. The appearance of these switchboards was further enhanced when the semi-flush type meters, instruments, and relays were designed, and later when draw-out features were added to these devices to provide greater accessibility for calibration and maintenance.

The standardization of switchgear permitted the use of shop punching, forming and welding by the manufacturers with the consequent lower costs for the user. Silver plating of contacts and current-carrying joints together with improved insulating materials has also contributed generally to greater reliability and continuity of service of modern metal-clad switchgear equipment.

An early development in automatic switchgear control was factory engineered and assembled control units. These units were later incorporated with the main circuit metal-clad equipment so that complete automatic station equipment is now procurable in factory assembled units.

Supervisory control and telemetering originally developed for electric railway substations and central station systems have been improved and expanded in application to many other fields by the controlled engineering and development of complete factory-built equipment using both metallic wire and carrier-current channels. Development is now under way to use microwave radio channels.

Foundation Laid

All of these developments in switchgear and those in the field of switchgear assemblies in particular have been the result of close cooperation between designers, manufacturers and users, and the already significant degree of standardization which has been achieved can be attributed to this cooperative effort. There still remains much to be done in the matter of standardization and improvement in design, but a firm foundation has been laid and the future should see rapid progress toward the achievement of this goal.

Interconnection and System Control

Connections between intra-company stations followed by inter-company ties to improve economy and reliability and minimize reserves
Evolution of frequency, tie-line control and dispatching boards

ONCE THE UTILITIES BEGAN to convert their systems from direct to alternating current, the demand for higher voltages increased rapidly since every time the voltage was doubled, the current was halved, and the losses in transmission on the same conductor sizes were quartered. By the time generating pressure reached 6 kv, steam turbines became available. Consequently, the combination of higher voltage and steam turbines immediately made it desirable to move generating stations to sources of condensing water supply which further increased the distances which energy must be transmitted and likewise increased the justification for still higher voltages.

Stations Tied

Tying of generating stations together to decrease the probability of service interruption also made possible the operation of the more economical equipment and correspondingly decreased use of less economical equipment. Furthermore, with stations interconnected, less total reserve was required to protect against the hazards of equipment failure.

Dispatchers and Boards

Previously each station had been on its own and no central control for power supply was necessary; but as systems grew and interconnected their stations, some central control was obviously necessary in order to handle the flow of power from one station to another for reasons of both safety and economy. The necessity for such an organization marked the advent of the so-called load dispatchers or power directors. They found necessary some means of keeping a continuous record of the system set-up and indications of the operations being performed. Dispatching boards thus came into existence and initially they consisted of nothing more than a single line blueprint with colored pins to indicate switching positions or a wooden panel with paper or painted diagrams equipped with colored plugs to denote switching positions as a record of the system set-up. These dispatching boards were extremely crude compared with many that exist today but, nevertheless, they served their purpose in providing a memorandum of the system set-up.

Voltages Rise

At the close of World War I many systems were completely interconnected within themselves, but the transmission voltage was seldom higher than the generating voltage of 13,000 volts which had been well established as the most practical generating voltage by that time; however, some companies had gone to twice this voltage for their so-called system backbones.

Radial ties to isolated sections of adjacent utilities constituted the first form of inter-company interconnection. The ties were almost always of relatively low capacity and do not compare in practicality with the larger interconnections of today. Furthermore, they were not interconnections as understood today because they were built with the definite intention that power would flow in one direction only. Contracts for such service provided for the delivery of what is now known as firm power and provided for usage at a specified minimum load factor for the established demand.

Large-Scale Interconnection

On the other hand, men of vision realized that high capacity interconnections would make it possible to carry the loads of two or more systems from less aggregate installed generating capacity, with consequent saving in investment and operating expenses due to the existence between the systems of load

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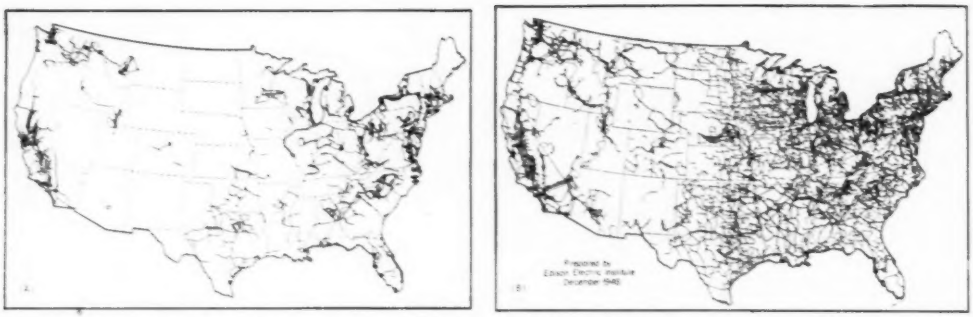


EXTENT of transmission lines and interconnections in 1928 (A) and 1948 (B). Interconnections improve reliability and economy

diversity or non-coincidence of times of occurrences of their maximum loads. There was also potentially available a reserve diversity or non-coincidence of the times of use of reserve generating capacity.

Furthermore, these men realized that high capacity interconnections would enable emergency conditions in any particular system such as breakdowns of generating capacity, shortage of fuel, or unforeseen increases in load to be met with less likelihood of impairment of service to the public. In addition, it was obvious that such interconnections would make possible lower cost of service through increased use of the more economical generating facilities and corresponding decreased use of the less economical generating facilities; and it was also possible that such expansion would make it possible to plan and construct future installation of generating capacity in ways and at places which would result in lower cost of service.

Transmission Improves

By the late twenties, much better transmission line design was available as well as transmission voltages up to 220,000 v. It had been learned that the hazards of lightning to the transmission lines could be greatly alleviated through the use of ground wires and counterpoises. By this time communication facilities had become highly developed and along with this there were available excellent telemetering facilities. It was in this period that the 220,000 v Pennsylvania-New Jersey Interconnection was conceived and developed.

As transmission technique developed, it was also necessary to expand the load dispatching organizations as well as the equipment with which they were furnished. Consequently, pins and plugs were supplemented by electric lights on the load dispatcher's pilot board. This change made it possible for the dispatcher to record changes in the system set-up without leaving his control desk. Telemetering instruments, which record the load on generating stations and tie lines, also became essential in order that he might have a complete picture of the system load at all times as well as its allocation among the various stations.

As interconnections expanded and transmission lines were still limited in capacity, it was desirable to maintain more regular frequency so that variations in this function would not be responsible for overloading the relatively light tie-lines, and, as a result, the frequency meter was improved and redesigned so that it could be connected to the prime movers and vary their generation as the frequency varied from normal. This arrangement was not entirely satisfactory in view of the fact that it placed all of the burden for frequency control at one location; however, more recent improvements permit the utilization of tie line bias control along with frequency control, thereby greatly reducing the load swings on the master frequency station.

Prior to the standardization of frequency there was considerable complaint from the textile manufacturers because of the wide variation in frequency which was responsible for producing markings in the cloth as a result of the change in tension on the yarn with variation in speed. Utilization of accurate frequency meters and also automatic frequency control has eliminated this problem. In addition, it has made possible the selling of electric time to the public which assures accuracy within a few seconds at all times.

Board Complexity Wanes

Some companies went even further and equipped the load dispatcher's pilot board with remotely controlled lamps that were tied in directly with the switch position and which indicated instantly any failure on any particular circuit.

At this time the cycle probably went a little too far, since too many small sub-stations were equipped with remote indication on pilot boards. This latter type of dispatcher's board, however, is on the wane at the present time, since the present trend is in favor of the return to the simple type of board. The dispatch boards recently installed in both Chicago and Baltimore seem to embody the highly desirable qualities of extreme flexibility and good appearance, yet these boards are well adapted for making quick and easy corrections at any time the system transmission layout is changed. This advantage seems to have been accomplished through uniform spacing of holes and the use of adhesive symbols for lines.

On the older dispatch boards, the background color was generally black or cream; however, research has

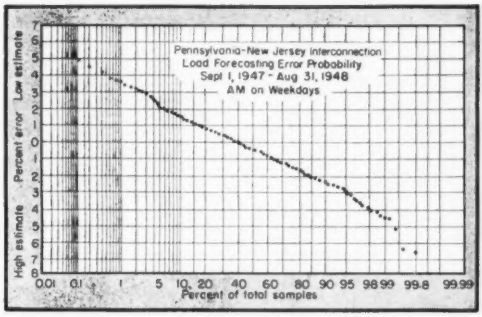

Pennsylvania-New Jersey Interconnection
Load Forecasting Error Probability
Sept 1, 1947 - Aug 31, 1948
AM on Weekdays
High estimate Percent error Low estimate
Percent of total samples

FIG 1—PROBABILITY of load forecasting error for week-day forenoons Sept 1, 1947, to Aug 31, 1948, on the Pennsylvania-New Jersey Interconnection

indicated that a medium green is more satisfactory. Furthermore, incandescent lighting has been superseded by high level (50 ft-c) fluorescent lighting, and air conditioning of the dispatching office has been utilized in many locations, since it has been realized that the load dispatcher's office is the heart of the system and it is, therefore, desirable to provide the utmost in comfort and convenience.

Unattended Stations

There is a current trend toward unattended substations and in some cases even unattended distant switching stations which are of considerable size and importance. This trend would seem to make it desirable to retain remote indications on the dispatcher's board for such conditions in order that the dispatcher may operate the bulk power system with confidence and speed, especially during major disturbances on the system.

Over a period of years, the method of transmitting indications of switch positions by telephone has been improved to a point where one pair of telephone wires can carry practically all the desirable indications from a remote generating or switching station. Carrier current is also available for this same purpose. Many dispatching centers of today are also equipped with radio equipment and weather instruments.

Reserves Minimized

The saving in operating reserve capacity which was initially forseen by the men who visualized the advantages of high capacity interconnections can be readily appreciated by referring to the tabulation shown in the table. This tabulation is a summation of the largest machines on each of the thirteen companies which are interconnected through the 220,000-v ring in the Pennsylvania-New Jersey Area. The sum of the thirteen largest units on the thirteen companies amounts to 671,000 kw, while at the present time the spinning reserve requirements for this area are only 236,000 kw, showing a potential saving in spinning reserve of 435,000 kw. This statement may be contested on the basis that the interconnected companies in this area would not have installed generators of this size if they had not been interconnected, but if this viewpoint is taken it must be admitted that interconnection has made possible the economical installation of larger units with consequent reduction in capital cost per kw as well as a reduction in operating expense.

Several Large Grids

At the present time there are about six large interconnections in the United States which range in size from 5,000,000 to 20,000,000 kw. The largest interconnection in the United States at the present time when considered on a basis of the total combined interconnected load is located in the central part of the country. This interconnected area covers approximately eighteen states, having a combined peak load of about 20,000,000 kw. Other large interconnections are located in the Pacific Northwest, the Southwest, the Southeast, and the Northeast.

Tie-line Load Control

In systems composed of relatively light interconnecting ties, it is practically essential that automatic tie line control be utilized since the various tie lines constituting the backbone of the interconnected area are of limited capacity and, consequently, thwart any centralized control. Schedules for the interchange of power under these conditions are made from hour to hour or period to period, and it is essential that the tie-line schedules be accurately maintained to avert disturbances to the frequency as well as the flow contracted for on other ties.

In this type of interconnection it is rarely practical or possible to reduce the spinning reserve capacity to the low figure which would be possible if adequate tie lines were available, since all of the reserve in the interconnected area is not available to every particular point within that area.

Adequacy of Interconnections

On interconnections having very heavy ties, where adequate tie line facilities are available and it is possible to reduce spinning reserve to a minimum, savings are possible through the utilization of a central interconnection office which is primarily responsible for the loading of all the equipment in the area under consideration. The Pennsylvania-New Jersey Area constitutes this type of interconnection, and the savings in spinning reserve are illustrated in Table I on page 146. The reserve requirements upon such an interconnection are not determined in most cases by the size of the units installed, but by the total load involved, since the greatest hazard to the interconnected group is the daily load forcasting error which exceeds the size of the largest unit by about 40%.

Reserve is insurance, and like all insurance the amount of reserve carried is primarily dependent upon the amount of money one wishes to spend for a given amount of protection. Fig 1, constitutes a load forecasting error probability curve for the Pennsylvania-New Jersey Interconnection over the period from September 1, 1947 until August 31, 1948 at the time

of the weekday morning peak. During the period when the samples for this curve were accumulated, the load forecasters were inclined to estimate their system loads slightly higher than those which actually materialized. This tendency can be detected by the fact that the curve passes through 50% of the total samples at a point about ½ of 1% below zero error. The curve also indicates that during 40% of the time (lower scale) the load exceeded the estimate, while during the remaining 60% of the time the load was actually less than the estimate. The last point plotted on this curve (upper left) indicates that the estimate was 5% too low during 1/10 of 1% of the time (lower scale). It may, therefore, be stated that in one case out of one thousand the load will exceed the estimate by 5%, and if this amount of reserve were regularly scheduled the system would go over the peak period without any reserve about once every four years.

With such information as this available it is only necessary to decide on the protection that is desired or the hazard which one is willing to risk and, therefrom, is established the spinning reserve requirements of the area under consideration. At the present time the Pennsylvania-New Jersey Area is carrying reserve of approximately 5.6% which indicates a hazard of no reserve once every eight years.

Seasonal Curve

One of the most recent problems which has confronted many electric utilities in the United States is a material change in the shape of the seasonality curve. Prior to World War II, many companies experienced a material drop in load during the spring and summer months which made space available for handling maintenance schedules, but in many areas this summer drop has almost, if not completely, disappeared. Fig 2 illustrates the change in shape of the seasonality curve on the Pennsylvania-New Jersey Interconnection between 1935 and 1948. It shows a material decrease in the space available for maintenance purposes. Very close coordination of interconnection maintenance schedules, as well as close cooperation by the participating parties, is now essential if reserve capacity is not to be sacrificed. In some areas it has actually become necessary to install additional capacity for the exclusive purposes of conducting maintenance schedules, and should the trend continue, the problem will become increasingly difficult.

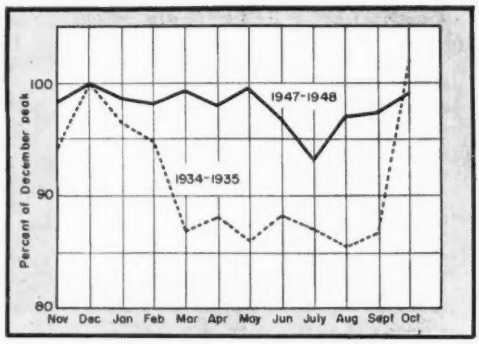


FIG 2—CHANGE IN MONTHLY PEAKS as percentage of December peak shows shift in seasonal characteristics

TABLE I—Saving in Reserve of Interconnection F.P.C. Area No. 5, Largest Units, by Companies

Company	Largest Unit
Public Service Elec & Gas Co	125,000 kw
Philadelphia Electric Co	182,000 kw
Pennsylvania Pwr & Lt Co	45,000 kw
Scranton Electric Co	45,000 kw
Luzerne County Gas & Elec Co	23,000 kw
Metropolitan Edison Co	50,000 kw
New Jersey Pwr & Lt Co	54,000 kw
Jersey Central Pwr & Lt Co	35,000 kw
Staten Island Edison Corp	25,000 kw
Delaware Pwr & Lt Co	7,000 kw
Atlantic City Elec Co	54,000 kw
Rockland Electric Co	22,000 kw
Edison Lt & Pwr Co of York	4,000 kw
Total of Units	671,000 kw
Area No. 5 Spinning Reserve Requirement	236,000 kw
Difference	435,000 kw

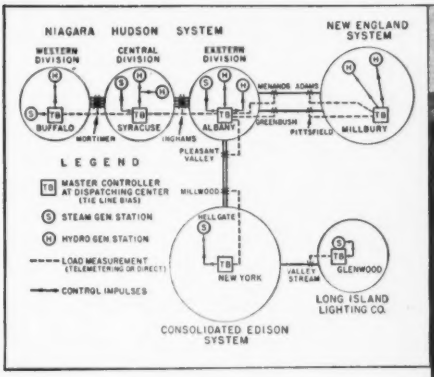
Station Rating

The change in the shape of the seasonality curve will in some cases necessitate the rerating of generating stations, since under the modern seasonality curve a station must be able to produce its rated capacity over a considerable portion of the year and inability to produce this rating thwarts the maintenance schedules. The old time procedure of rating a station on the basis of what it could do over the peak period of the year, therefore, cannot be adhered to, and unless this condition is taken into consideration, the effective capability of generating capacity is grossly misrepresented. Operating companies that do not rate their capacity on this basis will find it necessary to lean on their neighbors in an unfair manner in order that maintenance schedules might be fulfilled.

Saturday loads have dropped off materially with the five day week, while weekly peaks are maintained at a high figure during the greater part of the year. Although there may be no material change in the annual load factor, there is a considerable increase in the number of weeks at which a plant must operate or be prepared to operate at its full rating. This fact must be taken into consideration by members of interconnected groups in order that capacity obligations within the group can be correctly determined.

Pending Issues

Central control, correct rating of stations, and equitable adjustments for capacity deficiency are among the principal problems confronting interconnected groups today. Their timely solution will result in improved economy and better relations in interconnected groups.



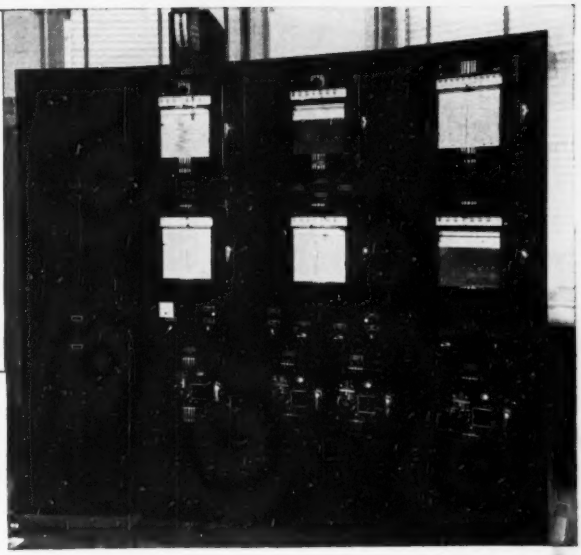


Diagram shows load-frequency control areas of the Northeast Interconnection. At right, the system's L&N master load-frequency equipment for centralized control of tie line and station loading.

Interconnection Carries Heavier Tie Loads With Help Of L&N Load-Frequency Control

The 7-million-kw Northeast Interconnection* which supplies electric power to large areas of New York State and New England, relies on tie-line bias control for load-frequency regulation of all the ties indicated in the above diagram—and the System likes the results.

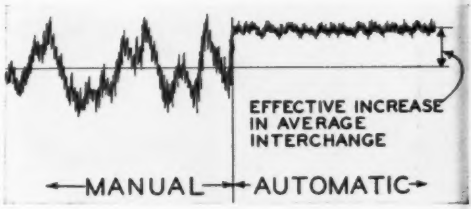
As with other interconnections using the bias method, this network "went through all the early stages" of control—first flat frequency, then selective frequency, then tie line bias. They say "we have continued to expand (tie-line bias control) within the respective Systems, to provide better and better control of the load and therefore better frequency control of the whole interconnection".

"Good Neighbor Policy" Of Stations

The Control permits each generating station to be a good electrical neighbor to the others in its interconnection. While many stations operate on the basis of dispatched load, each area is responsible for correcting its own load variations, and scheduled transfers can be worked out between stations for economy or emergency reasons.

Ties Carry Heavier Loads

Regarding the problem of meeting the area's power needs, the Interconnection finds much help in the bias control. "If the interchange were permitted to vary," they say, "a greater operating margin would have to be maintained, between the average tie line load and ultimate carrying capacity. The control reduces fluctuations, therefore closes the gap between actual load and available capacity". This situation is diagrammed in the accompanying illustration.



Visualization of the load-carrying increase of a tie line possible with L&N Load-Frequency Control for tie-line-bias regulation.

L&N equipment is available not only for tie-line load control, but for any other type of regulation. We will be glad to send you the general description, but if you have a specific problem, we suggest that you give us the significant details so that we can more clearly present the pertinent facts. Address Leeds & Northrup Co., 4938 Stenton Ave., Philadelphia 44, Pa.

*See "Load-Frequency Control on the Northeast Interconnection" by McCormack & Metcalf in *Electric Light & Power* Feb. 1949. Reprint N-56(2) from L&N on request.

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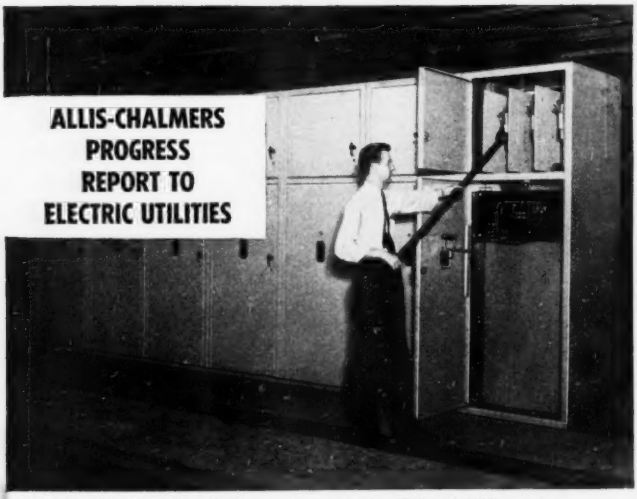
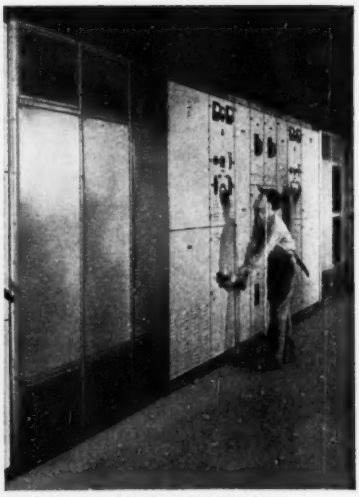
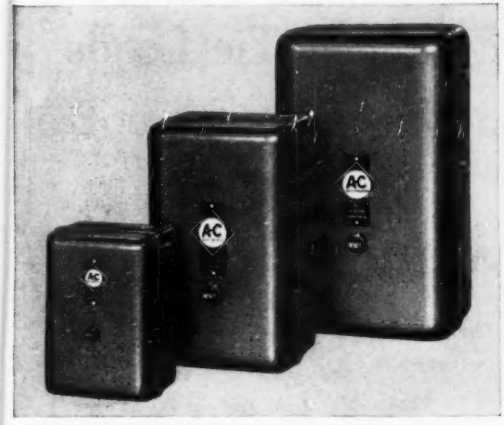
ALLIS-CHALMERS PROGRESS REPORT TO ELECTRIC UTILITIES



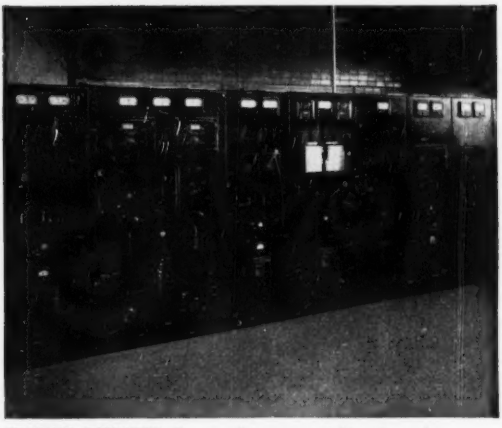
HIGH INTERRUPTING CAPACITY type "H" starters for 2300 and 4600 v service



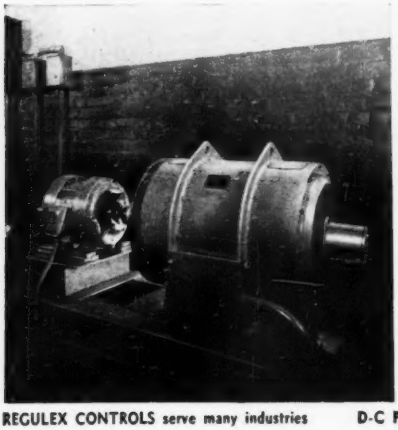
ECONOMICAL POWER CONVERSION with metal-enclosed rectifiers



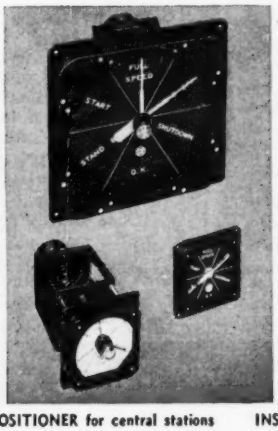
GENERAL PURPOSE across-the-line starters, all NEMA ratings



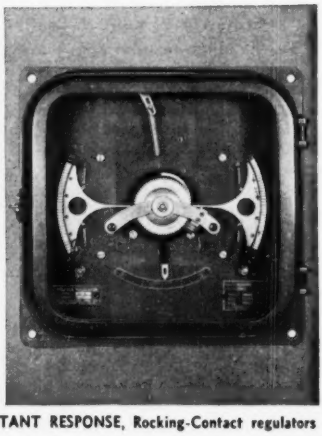
SYNCHRO-OPERATOR, 2 v. regulators on switchboard panel



REGULEX CONTROLS serve many industries



D-C POSITIONER for central stations



INSTANT RESPONSE, Rocking-Contact regulators

Motor Control Line Broadened, Duplex Switchboards Improved

F. C. Ludington, Mgr., Control, Switchgear

ALLIS-CHALMERS now offers a wide selection of up-to-date control for cage, wound rotor, and synchronous motors; and, in addition, an excellent line of power plant control equipment.

MOTOR STARTERS. Allis-Chalmers control line includes full or reduced voltage starters, magnetic or manual—for synchronous motors to 3000 hp, 4600 volts; cage motors to 2500 hp, 4600 volts. Also magnetic primary and secondary control for wound rotor motors, and drums for manual secondary control. A-c general purpose magnetic starters, local or remote controlled, are available for motors through 600 hp. For 2300 and 4600-volt service, Type H high interrupting capacity current limiting fused starters are offered.

WOUND ROTOR CONTROL. Secondary control of large wound rotor motors for induced and forced draft fans utilizes a new design of liquid rheostat offering compactness, wide range of speed control, freedom from flash over, and resistance characteristic to suit load.

DEVICES. Under continual development are various control devices to assure safer, more dependable operation for both standard and special controls. These include a-c and d-c contactors, rotary control switches, voltage, current and timing relays, thermal overload relays, resistors, pushbuttons, etc.

VOLTAGE REGULATION. Rocking contact voltage regulators have been revised for greater sensitivity and speed of response, with fewer moving parts. Electrical damping has replaced eddy current damping.

When field forcing is required for extremely fast response and high accuracy, *Regulex* rotating voltage regulators are used. Regulex control can be used to control large blocks of power with extreme rapidity and sensitivity through small changes in almost any function such as speed, tension, acceleration, deceleration, position, torque, etc., which can be converted into volts, amperes or watts.

REMOTE INDICATION AND CONTROL. The d-c positioner is finding more applications in central stations. Lack of tendency to hunt, motorize, or lose synchronization meets exacting dependability and accuracy standards. Applications have included remote indicating, positioning and order telegraph service, remote hydraulic governor regulators, liquid level and tap change indication. On turbines, applications include: lever-connected transmitters to measure and record relative expansion in turbine; indicate turbine load limit position when changed either at turbine or remotely from switchboard; and indicate tie-in regulator position (regulator controls turbine output at certain periods).

★ ★ ★

SWITCHBOARDS. Among Utility and industrial customers desiring greater space savings in control and generating rooms Allis-Chalmers Duplex Switchboards are effecting worthwhile economies. Departing from conventional switchboards, incorporating circuit breakers, buses, instruments and controls, duplex boards have indicating instruments and control switches on the front panels within easy reach. Less frequently used relays and recording instruments are mounted on rear panels. Doors at both ends permit easy access to wiring on back of panels. Interiors are well-lighted. The switchgear with breakers, buses, etc., is installed remote from control and relaying equipment.

Other types of switchboards (for primary and secondary control), vertical panels, benchboards, control desks, are also offered. Available as standard units or custom-built to meet special requirements. Standard panels available for controlling generators, feeders, incoming lines, transformers, exciters, rotary converters, motors. Custom-built boards for generating station, mill, rectifier, process control, etc. Additions to existing boards can be matched as required.

★ ★ ★

During 65 years of service to the electric power industry "A-C" has developed literally the world's largest line of major equipment for electric power—and the control to go with it.

The progress shown above is typical of the advanced design planning that makes Allis-Chalmers a good name to know and call-on in electric power equipment! ALLIS-CHALMERS, 932A S. 70TH ST., MILWAUKEE 1, WIS.

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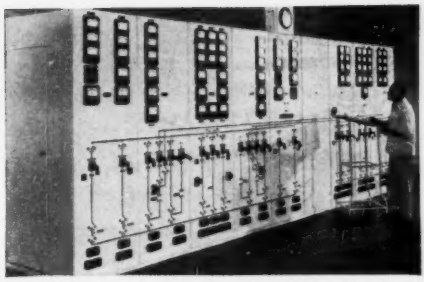
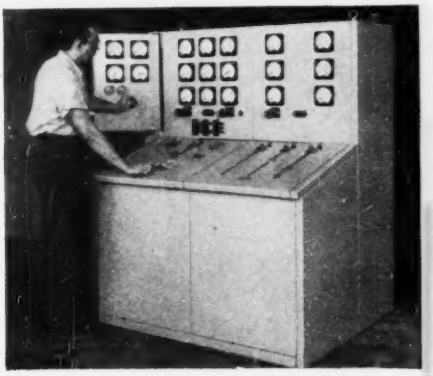
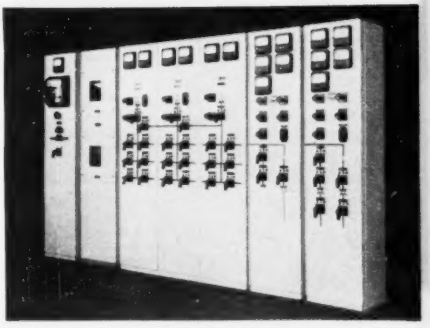
ALLIS-CHALMERS



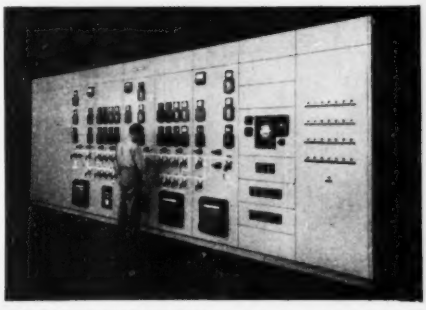
DUPLEX SWITCHBOARDS gain preference; 9-panel unit



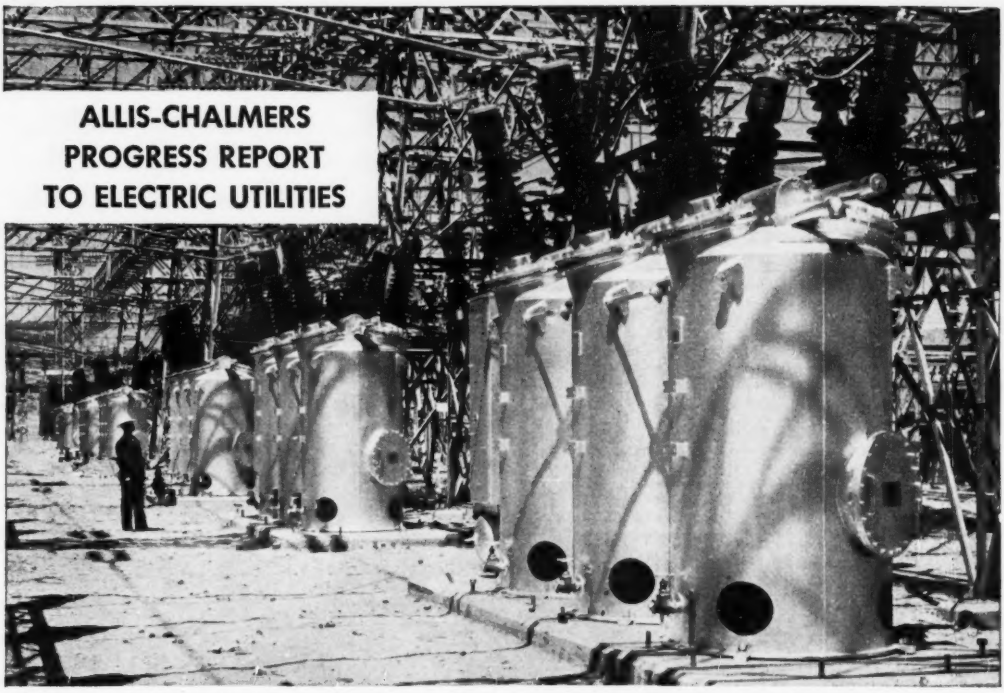
BENCHBOARDS available standard or custom-built



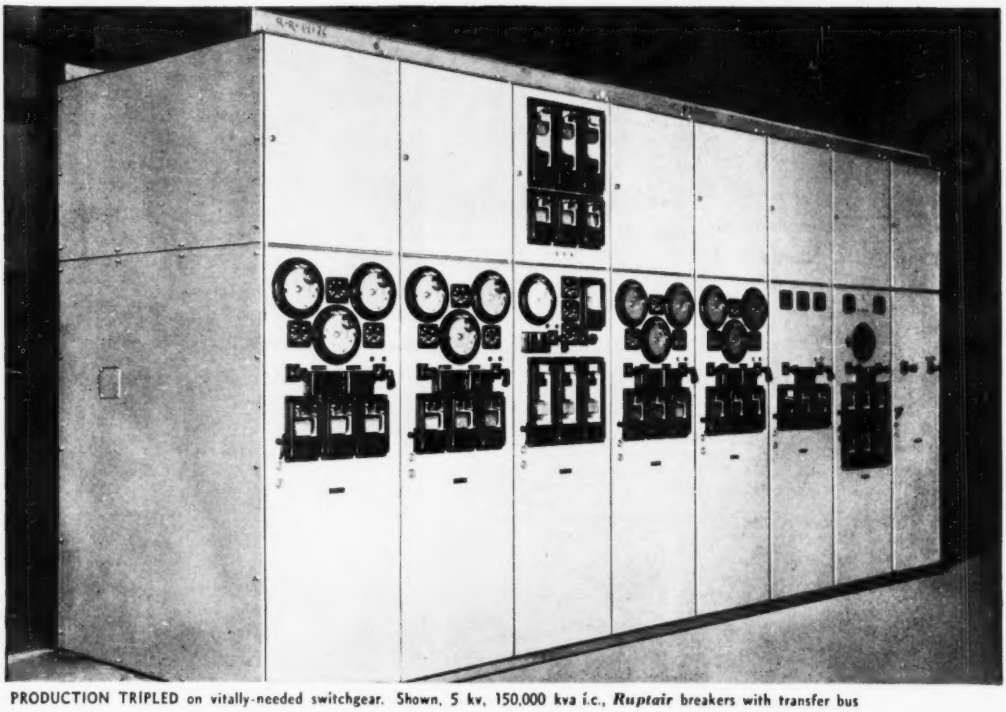
VERTICAL CONTROL PANEL for Midwest power plant



INDICATING INSTRUMENTS, switches, etc. in easy reach



2,500,000 KVA I.C. OUTDOOR OIL CIRCUIT BREAKERS—3 pole, single-throw, 800 amp, 115 kv, pneumatically operated



PRODUCTION TRIPLED on vitally-needed switchgear. Shown, 5 kv, 150,000 kva i.c., *Ruptair* breakers with transfer bus

New Standards, New Facilities Characterize Power Circuit Breaker and Switchgear Production

POWER CIRCUIT BREAKERS. During the past year many new standards have been introduced to meet Utilities' increasing demands for greater interrupting capacities and higher operating speeds.

L. W. Long, Gen. Mgr., Boston Works, Circuit Breakers

A-C enters its fiftieth year of circuit breaker manufacturing with a complete line of indoor and outdoor units.

Outdoor. A line of modern all-welded, functional oil breakers from 50,000 kva, 7.2 kv up includes:

The *Unitop* breaker from 14.4 to 46 kv, 8-cycle opening, 20-cycle reclosing. A new design of the 69 kv line, including new ratings and higher speeds at 5 and 8-cycle opening, 20-cycle reclosing. A new design of supervoltage line, 115 kv and up, ratings to 5,000,000 kva, 3 and 5-cycle opening, 20-cycle reclosing.

Standard on high-speed reclosing breakers is the pneumatic operator with mechanically trip-free mechanism. Development on breaker control cabinet incorporating this mechanism has improved accessibility, appearance.

Indoor. A most important development is the new indoor oilless power circuit breaker for heavy duty operation. It combines interrupting features of axial blast with structural and current-carrying contact advantage of the cross-blast breakers. With this new air-blast design the line of oilless indoor breakers is complete from 4.16 to 14.4 kv, up to 2,500,000 kva interrupting capacity.

★ ★ ★

SWITCHGEAR. Assembly-line production, from raw materials to completed units, has tripled output. Improved facilities include: new 32-station panel punch presses; new hot phosphate spray tunnel ahead of painting; new 60-foot infra-red tunnel that bakes paint from inside-out, for longer-lasting finish.

Among design changes, basic structures now provide complete segregation of buses, control wiring, instrument transformers, etc., without impairing accessibility.

Redesigned outdoor metal-clad switchgear has welded-in floor plates, full-length instrument panels, improved ventilation, more space for mounting auxiliaries.

Cubicle switchgear for service in excess of 14.4 kv, with interrupting capacity from 500 to 2,500,000 kva is now offered. Completely metal-enclosed, it uses stationary air blast breakers (see Power Circuit Breaker section left), including thorough phase segregation for protection of circuits and operating personnel.

Low voltage switchgear, to 600 v. a-c, is standardized on a single main bus which eliminates congested bus areas, simplifies inspection. Bus transition units can be eliminated, saving floor space. Instruments, etc., are mounted on auxiliary units for better accessibility.

Type G-25 and G-50 air circuit breakers, for mounting in low voltage metal-enclosed switchgear or in individual enclosures have been improved. Manually or electrically operated, available with inverse-time series overcurrent trip, etc.

Where existing breakers are inadequate, the Type "Y" *Ruptair* circuit breaker replacement unit is offered. Rated 5,000 volts, interrupting capacity through 250,000 kva. Economically installed—utilizing existing cables, buses, switches, transformers, etc.

★ ★ ★

In 1899, what is now Allis-Chalmers' Boston plant was founded to build some of the earliest commercial oil circuit breakers. In 1926, Allis-Chalmers introduced the first metal-clad switchgear in America, outmoding open-type, piecemeal switching centers. The same kind of experience and pioneering extends to every line of major apparatus A-C builds for the electric power industry—makes A-C a good firm with which to do business! ALLIS-CHALMERS, 932A S. 70TH ST., MILWAUKEE 1, WIS. A2717

Unitop and Ruptair are Allis-Chalmers Trademarks

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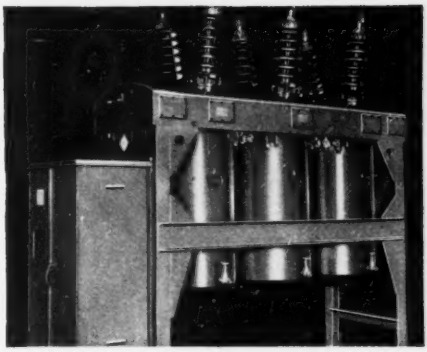
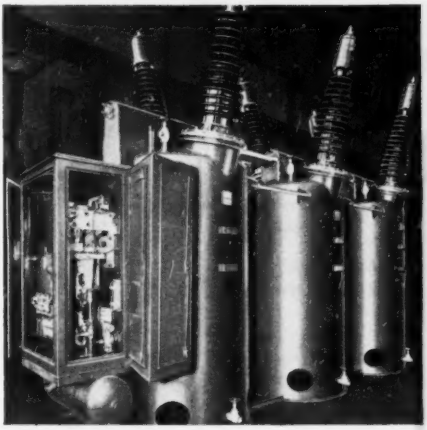
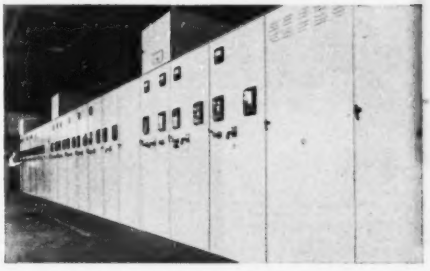


TYPE FZO-151, 600 amp, 46 kv, 500,000 kva i.c.



TYPE BZO-160, 1200 amp, 161 kv, 3,500,000 kva i.c.

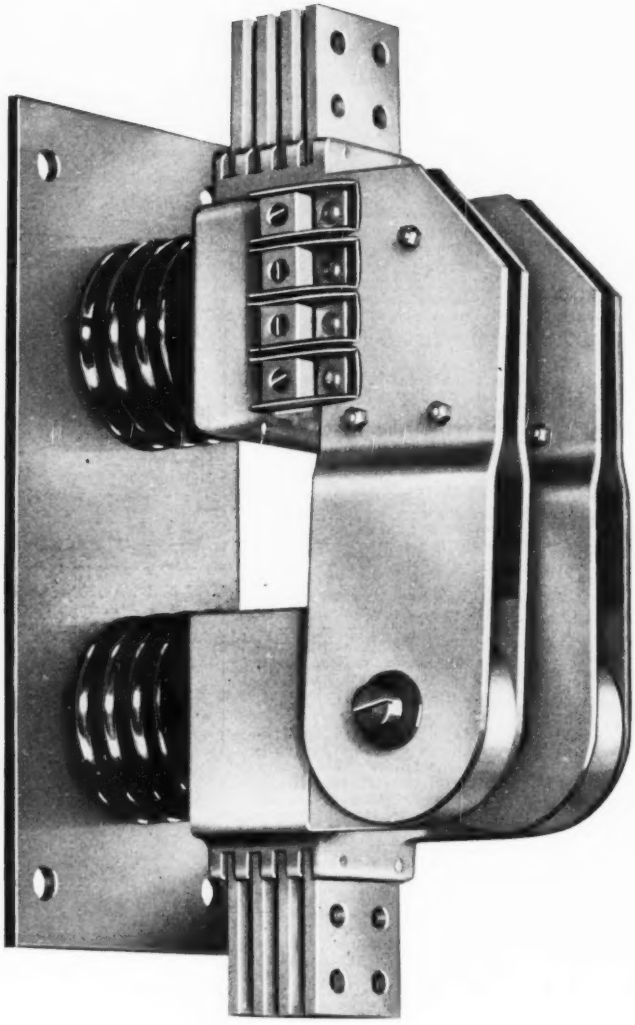


FIFTEEN 250,000 Kva, air-blast switchgear units

RUPTAIR Switchgear replacement units for utilities

Cole Electric Co.

8439 Steller Drive TExas 0-4701 Culver City, Calif.



INDOOR DISCONNECTING SWITCH
7500 Volts—3000 Amperes, Type XY2
Three pole, single throw
Remote manual, group operated
(1 pole shown)
See Bulletin 10-A

Silver DEPOSITS

ON BUSES AND SWITCH GEAR

INDUSTRIAL BRUSH ELECTRO-PLATING

is a low-cost, efficient and practical method of applying permanent pure silver* deposits on electrical equipment.

Economy: This original Brush Plating process applies the finest plating possible. Electrodeposits are applied only where the applicator is used. Plating costs can be reduced and placed under complete control.

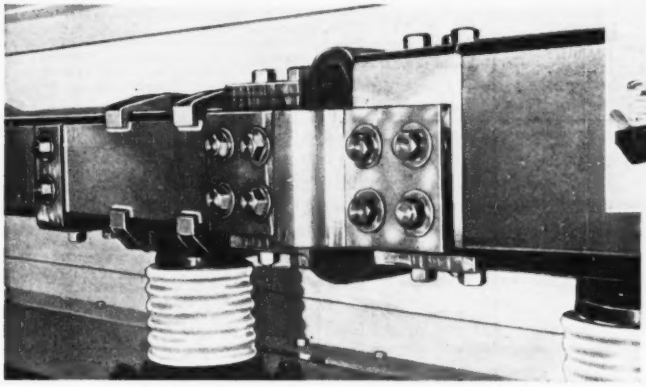
Availability: The efficient power unit and solutions are always ready for instant use — anywhere. Use it on equipment "in place" or during manufacture — No service interruptions.

Simplicity: An average worker will learn the correct method of use in less than thirty minutes.

*The electrodeposits of this process are 99.9% plus, pure silver.

- **Brush Electroplating permits rehabilitation of obsolete equipment**
- **insures positive protection to strategic metals**
- **eliminates destructive oxidation**
- **pure silver gives greater electrical conductivity**
- **helps prevent loss of power**
- **gives longer and more satisfactory performance to present electrical equipment**
- **approved and used extensively by United States Army and Navy — Industrial plants and most Power Companies**

*Also applicable for other metals, gold cadmium, zinc, nickel, tin, etc.



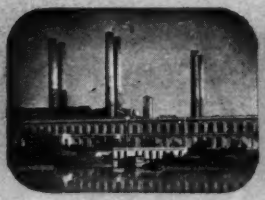
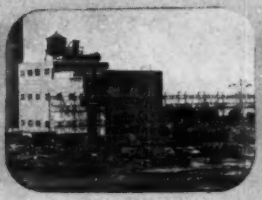
NEW LOW group price for complete outfit ready for use as illustrated, only $215.00, f.o.b. Chicago. Brushes are made of Nylon bristles and are unaffected by normal plating solutions. The above installation is all you need for this modern electroplating process.

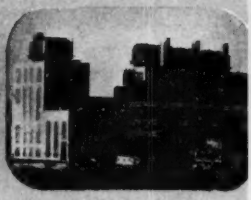
AJAX-CONSOLIDATED COMPANY

Service to Utilities . . . Industry and Railroads

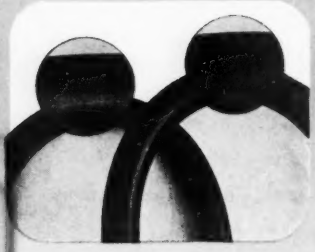
4621 WEST 20TH STREET • • • • • CHICAGO 50, ILLINOIS

OKOLITE-OKOPRENE CABLES ARE INSTALLED



WHY STATIONS HAVE STANDARDIZED ON



Thirteen years exposure in Okonite's outdoor proving ground clearly shows that Okoprene sheaths are unimpaired while rubber coverings "check" and deteriorate.

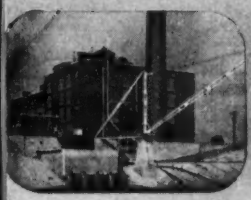
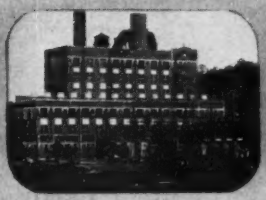
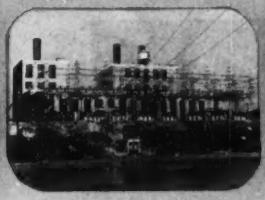
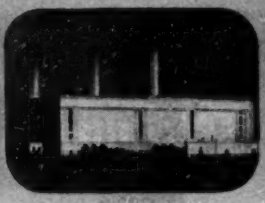
The effects of atmospheric exposure in contributing to cable deterioration are studied in this test cell developed by the Bell Laboratories.

LOW COST INSTALLATION AND OPERATION

The complete simplicity of Okolite-Okoprene cables reduces weights and handling problems to a minimum and eliminates corrosion and electrolysis since no lead sheath is required. Splicing and terminating methods are also greatly simplified as potheads, lead sleeves and filling compounds are unnecessary.

PROPERTIES	LOCATIONS	OKOLITE-OKOPRENE PROPERTIES
LONG LIFE AND RELIABILITY	All electrical circuits.	Confirming nearly a quarter-century of field experience, continuous aging tests of Okolite insulation checked at intervals in Okonite's proving ground, show practically no change in physical and electrical characteristics. Okolite oil-base insulation, applied by Okonite's strip process, is made with wild Up-river Fine Para rubber established over many years of steady use as stable and dependable. Exposure tests and service records over 13 years have proved the durability of Okoprene coverings.
ELECTRICAL STABILITY	All control, power, lighting, and switchboard circuits.	Electrical measurements made on Okolite insulation after 8 years immersion in water show the insulation resistance unchanged from the excellent values recorded in the first 6 months. Insulations made with synthetic rubbers show no such stability. Retention of Okolite's stable electrical qualities is further insured by the Okoprene sheath that seals the insulation from terminal to terminal.
HIGH DIELECTRIC STRENGTH AND OZONE RESISTANCE	Generator and transformer leads, auxiliary power circuits, test cables, etc.	Okolite's high dielectric strength is greatly increased by the use of Semicon tape over conductors operating above 2000 volts. Therefore, in addition to a-c. tests at voltages 25% greater than IPCEA requirements, all such Okolite-Okoprene cables are also given a self-imposed d-c. kenetron test at 3 to 4 times the IPCEA 60-cycle a-c. values. Internal and external ozone attack is resisted in 4 ways: (1) Okolite insulation is ozone-resistant, (2) Semicon tape prevents internal corona discharge, (3) Okoprene covering is not only ozone-resistant but (4) does not develop static discharge below 5000 volts.
MOISTURE RESISTANCE	Cables in ducts, troughs, or buried direct and wherever condensation exists.	Okolite insulation—*without any lead covering*—has been used for 20 years in submarine power cables, some of which operate at 35,000 volts. From its Okoprene sheath that cannot rot to its conductor coated with Okoloy — the lead alloy that outlasts tinning 2 to 1 — an Okolite-Okoprene cable resists attack by moisture.
HEAT AND FLAME RESISTANCE	Boiler rooms, tunnels, and other hot locations and for heavily-loaded cables.	Okolite insulation, recommended for use at 75 degrees C up to 8000 volts and 70 degrees C above 8000 volts, is suitable for heavy current loadings or for hot locations. Since equally heat-resistant Okoprene coverings will not support combustion, Okolite-Okoprene cables are also non-flammable, a feature of prime importance in station design.

IN THESE WELL-KNOWN CENTRAL STATIONS

OKOLITE-OKOPRENE WIRES AND CABLES

Switchboard wire at its simplest: Okoloy-coated conductor and Okolite-Okoprene covering.

For lower voltage power and lighting circuits: Single conductor Okolite-Okoprene wire.

Station auxiliaries and other higher voltage Okolite-Okoprene cables have Semicon tape over conductor.

Multi-conductor control cables have colored Okoprene (plain or striped) for coding.

Okolite-Okoprene cables can be supplied with interlocked bronze armor.

Whether it's new or old, large or small, there's no central station today that is not a *key* station – the heart of its community's electrical system. Engineers and officials cannot afford to take chances where a single outage can disrupt an entire area. That is why Okolite-Okoprene wires and cables are standard for station equipment.

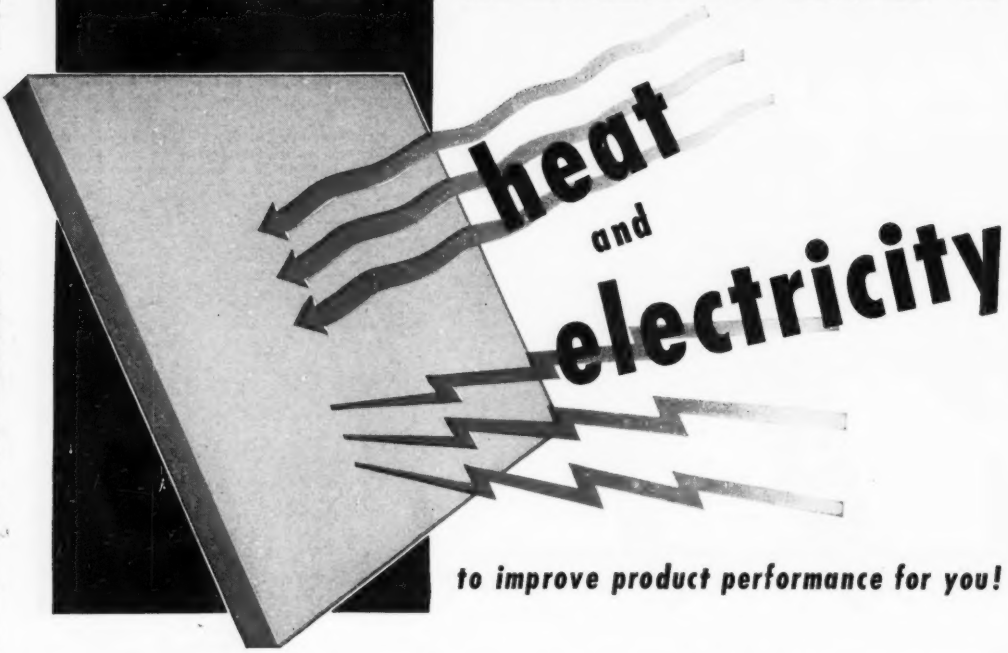
Okolite-Okoprene station wires and cables are available in a complete range of designs from switchboard wire and control cables to heavy, shielded generator leads of the largest dimensions. For circuit identification individual conductors can be supplied with colored Okoprene coverings. Many utilities prefer to use single conductor cables, on reels individually, or wound three cables in parallel, or twisted together without other coverings. Others are obtaining multi-conductor assemblies with an over-all Okoprene jacket.

Okolite-Okoprene cables may be installed in conduit, on trays or racks, buried direct or exposed to the weather. For complete information, including current carrying capacities, dimensional data and splicing instructions ask your Okonite representative for the Okolite-Okoprene Data File or write direct to The Okonite Company, Passaic, New Jersey.

Okolite-Okoprene generator lead: Semicon tape protection over segmental conductor, heavy wall of Okolite insulation, metal shielding tape and non-flammable, non-metallic Okoprene sheath.

OKONITE insulated wires and cables

NEW C-D Silicone Dilecto withstands an inferno of



to improve product performance for you!

There are three new grades of C-D Dilecto* that can withstand temperatures as high as 250°C. They are chemically inert, silicone-glass laminated plastics that offer exceptionally high heat resistance and good arc resistance, extra strength, and positive moisture resistance! At Continental-Diamond we've literally lived and worked with Silicone Dilecto—perfecting it to a point where we believe it can be highly useful in helping to solve your production problems — and improve product performance.

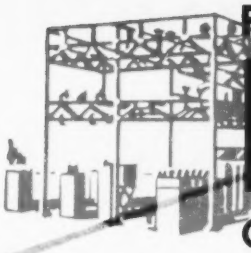
And this remarkable plastic is but one of many in the C-D family. They provide practical combinations of mechanical, electrical, and chemical properties—structural strength, light weight, positive moisture, heat and corrosion resistance. In hundreds of plants, C-D Plastics—Fibre, Vulcoid, Dilecto, Celoron, and Micabond—offer proof that it pays to see C-D first in your search for the right plastic for the job. For interesting, useful information on Silicone Dilecto, and other C-D high strength plastics, call or write your nearest C-D office, soon.

your partner in producing better products

*Dilecto GB—112—S
Dilecto GB—128—S
Dilecto GB—261—S

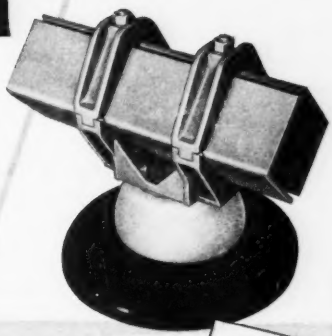
DE-2-49
BRANCH OFFICES: NEW YORK 17 • CLEVELAND 14 • CHICAGO 11 • SPARTANBURG, S. C. • SALES OFFICES IN PRINCIPAL CITIES
WEST COAST REPRESENTATIVE: MARWOOD LTD., SAN FRANCISCO 3 • IN CANADA: DIAMOND STATE FIBRE CO. OF CANADA, LTD., TORONTO 8

Continental-Diamond FIBRE COMPANY
Established 1895 . . . Manufacturers of Laminated Plastics since 1911 — NEWARK 15 DELAWARE



FOR POWER CONNECTIONS

The comprehensive Burndy line includes connectors for every substation requirement . . . T connectors, couplers, expansion joints, ground connectors . . . bus support clamps for all types and sizes of tubing, flat bar and cable. All meet rigid utility requirements, both electrical and mechanical. Ask for descriptive literature, or engineering assistance. BURNDY Engineering Company, New York 54, N. Y. WESTERN BRANCH: Vernon 11, California. CANADA: Canadian Line Materials, Ltd., Toronto 13.

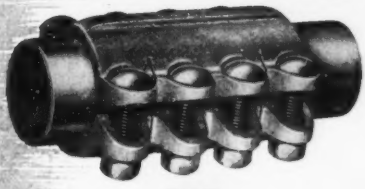


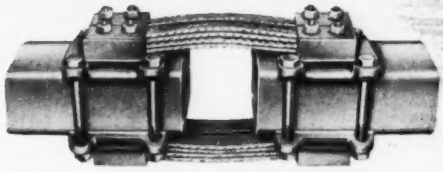
ANGLE BUS SUPPORT CLAMP
Type BH-L

25 YEARS OF SERVICE

Connect with BURNDY

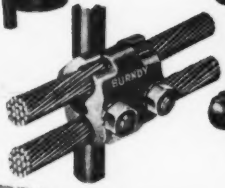
COUPLER
Type NS

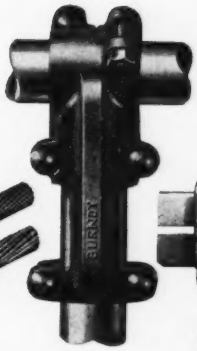


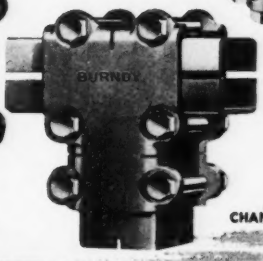


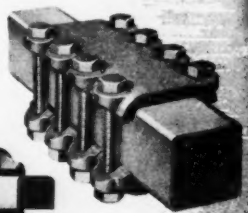
SQUARE BUS EXPANSION COUPLER
Type XPL-T

GROUND CONNECTOR
Type GAR









SQUARE BUS COUPLER
Type NS-T

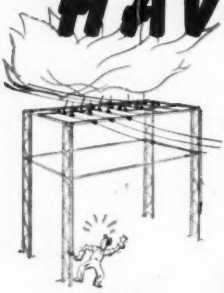
GROUND CONNECTOR
Type GB

GROUND CONNECTOR
Type GP

T-CONNECTOR
Type CT

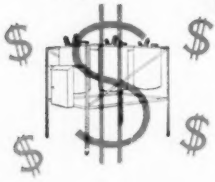
CHANNEL T-CONNECTOR
Type NT-S-90

HAVE YOU SWITCHING



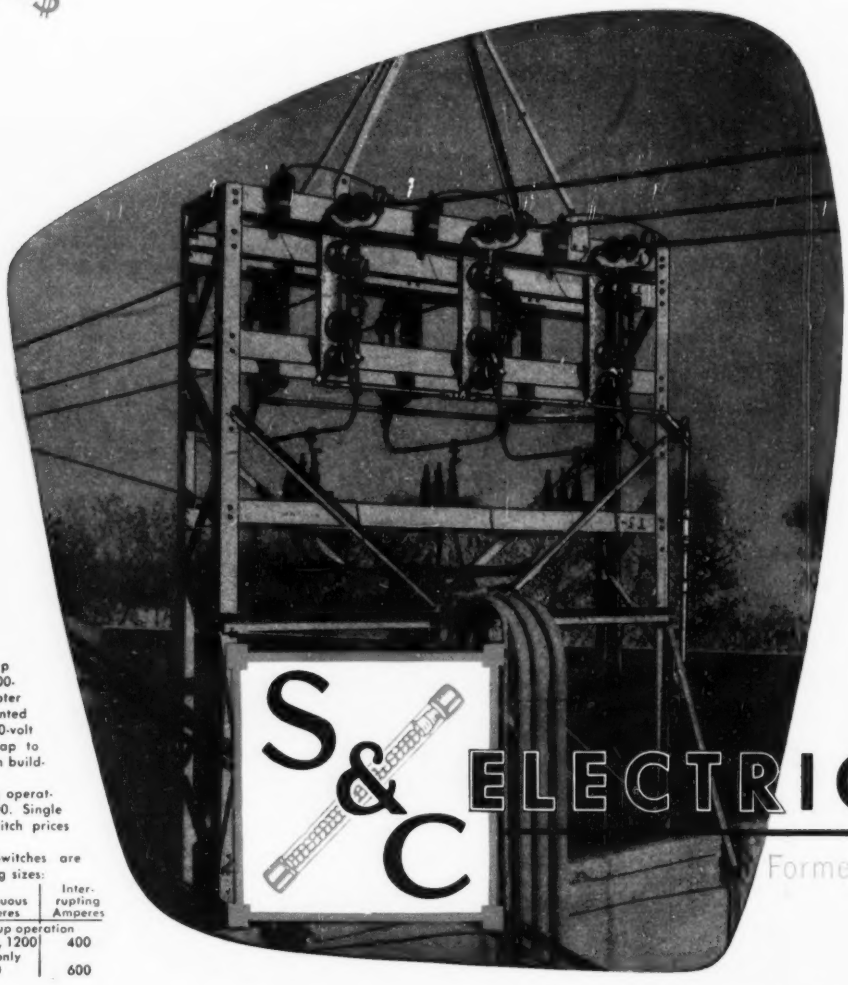
① Where Horn Gap Switches Are Inadequate

because they cannot, under all conditions, safely break magnetizing or charging currents; nor can they interrupt load currents



② Where Circuit Breakers Are Becoming Too Expensive

for non-automatic switching and short circuit protection



Two three-pole, group operated, 7,500-volt, 400-ampere, Alduti Interrupter Switches vertically mounted back to back, in 2,300-volt overhead loop circuit tap to load-center substation in building below.

Price each, including operating mechanism, $490.00. Single pole stick operated switch prices as low as $65.00.

Alduti Interrupter Switches are supplied in the following sizes:

Volts	Continuous Amperes	Interrupting Amperes
For hook stick or group operation		
7500 & 15000	400, 600, 1200	400
For group operation only		
23000 & 34500	600	600

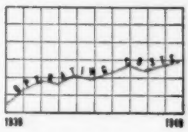
APPLICATIONS . . . . .

③ Where Structure Design Is Restricted

because horn gap switches can be mounted only in the horizontal upright position, need wide phase spacings, and always require an operating mechanism

④ Where Switching Sequences Are Too Complicated And Costly

because multiple operations—involving breakers, disconnects, and operating personnel—are required to isolate equipment or sectionalize circuits



ALDUTI INTERRUPTER SWITCHES

offer a proved and economical solution to such application problems.

Ten years of actual operating experience in thousands of installations, and many field trials under inordinately severe test conditions, have demonstrated convincingly the ability of these Interrupters to—safely and repeatedly—

Sectionalize either radial or loop distribution and subtransmission circuits, under either load or charging current conditions . . .

Switch load and magnetizing currents of transformer banks . . .

Switch charging currents of capacitor banks.

Because there is NO EXTERNAL ARCING during the operation of Alduti Interrupters: they need not be mounted only horizontally upright, but can also be mounted vertically, or horizontally underhung; hook stick operation can be employed where economy dictates; and phase spacings can be reduced to 18 inches for the 7,500-volt and 39 inches for the 34,500-volt switches. Hence structures can be smaller, connections simpler, and construction cost can be reduced below that of installing horn gap switches. Also, Alduti Interrupters can be installed in cubicles, thus providing—even for subtransmission applications—enclosed "packaged-type" switches, thereby permitting the complete enclosure of all components of a unit-type substation.

When combined with S&C Power Fuses, Alduti Fused Interrupters also provide short circuit protection with fault current interrupting ability up to 40,000 amperes asymmetrical, thus making possible the elimination of expensive circuit breakers where automatic switching is not required.

OPERATING, CONSTRUCTION, AND MOUNTING DETAILS, INTERRUPTING RATINGS, AND FIELD TEST REPORTS WILL BE MAILED ON REQUEST

S & C ELECTRIC COMPANY
4421 Ravenswood Avenue
Chicago 40, Illinois

☐ Please send complete information on ..... 7.5 kv, ... 15 kv, ... 23 kv, ... 34.5 kv Alduti Interrupter Switches

☐ Have representative call

Name ..... Title .....

Company .....

Street & Number .....

City ..... Zone ..... State .....

COMPANY

SCHWEITZER & CONRAD, INC.

NOW — ONE OF THE ELECTRICAL INDUSTRY'S MOST VERSATILE AND VALUABLE "TOOLS"

From the making of little electrical connections to husky joints on big generators, brazing with EASY-FLO and SIL-FOS is used today for thousands of different metal joining jobs in the original production, the installation and the repair of electrical apparatus and equipment.

To anyone familiar with what EASY-FLO and SIL-FOS can do, this industry-wide use comes as no surprise. For low-temperature EASY-FLO and SIL-FOS silver alloy brazing satisfies every requirement of metal joining for both current-carrying and structural purposes. It's simple . . . it's fast . . . it's reliable. It makes joints high in electrical conductivity . . . strong and enduring as the metals joined . . . at a surprisingly low cost per joint. Its low brazing temperature joins thin gauge metals safely. . . . And, as a fast, reliable, low-cost method of joining stampings, screw machine parts and die castings, the use of EASY-FLO and SIL-FOS brazed construction is constantly expanding.

GET THE FULL STORY IN THESE BULLETINS

These two bulletins will give you a clear picture of the remarkable versatility of EASY-FLO and SIL-FOS brazing and the reasons why it is so fast, reliable and economical. Write for copies today. Ask for Bulletins 12-A and 15.

PARTIAL LIST OF ELECTRICAL PRODUCTS MADE WITH THE AID OF ***EASY-FLO*** AND ***SIL-FO***.

APPLIANCES
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Controls
Fans
Heaters
Irons
Lamps
Mixers
Oil Burners
Reflector Lamps
Stoves
Teakettles
Toasters

EQUIPMENT
Alarm Systems
Brush Holders
Bus Bars
Circuit Breakers
Condensers
Contacts
Control Systems
Electric Furnaces
Electrode Holders
Electro-therapeutic
Field Connections
Fuses
Generators
Instruments
Leads and Terminals
Lugs
Melting Equipment
Meters
Motors
Outlet Boxes
Radar
Radio
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Refrigeration
Switches
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Transformers
Welding Equipment
Wire Connections
Wire & Cable Mfg.

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More Than 40 Years of Research and Experience is Your Assurance of Reliable Performance with

ROLLER-SMITH PRODUCTS!

PANEL INSTRUMENTS
1½" to 4½"—AC, DC and RF Ammeters, Milliammeters, Voltmeters, Millivometers, and Volume Level Meters.

AIR CIRCUIT BREAKERS
50 to 5000 Amperes, 600 volts AC. 250 volts DC. 25,000 Amperes to 100,000 Amperes, Interrupting Capacity. Manual or Electrical Operation, dead front and enclosed.

OIL CIRCUIT BREAKERS
Outdoor type, 400 to 600 Amperes, 7.5 & 15 KV. 50,000 to 100,000 KVA Interrupting Capacity, Manual or Electrical Operation.

PORTABLE INSTRUMENTS
3" to 8"—Small Pocket Type, Medium and Large Laboratory Type AC and DC Ammeters, Milliammeters, Voltmeters, Millivoltmeters, Wattmeters, Frequency Meters and Power Factor Meters.

TYPE R-2 ROTARY SWITCH
Instrument, Control and Auxiliary. For Electrical Instruments, Circuit Breakers and Transfer Application. Available in 88 Combinations.

MODEL B DOUBLE HOOK BALANCE
Precision Balances—For use in Assaying.—Research—Production Control—Analytical Work. For Accurate—Rapid Weighing.

SUBWAY OIL SWITCHES
200 to 600 Amperes, up to 15 KV. Manual Operation.

SWITCHBOARD INSTRUMENTS
4", 6" and 7" AC and DC Ammeters, Voltmeters, Wattmeters, Frequency Meters, Power Factor Meters, and Synchroscopes. Accuracy 1%. Also Precision **WATTHOUR METERS.**

EXOTHERM OIL BREAKERS
600 to 1200 Amperes, up to 15 KV, 50,000 to 250,000 KVA interrupting Capacity. Manual or Electrical Operation.

METAL CLAD SWITCHGEAR
Drawout Low Voltage Air Circuit Breaker Switchgear, 600 volt. Metal Clad Oil Circuit Breaker Switchgear, up to 15 KV.

You have discovered through the years that Roller-Smith is a name that signifies dependability.

Illustrated are ten products which are in wide use today and which have materially aided the advancement of the utility field.

For your convenience there are sales offices throughout the United States, with specific Manufacturers Representatives to complete the picture.

It was over 40 years ago that Roller-Smith appeared on the manufacturing scene, and subsequent research and experience resulted in our long line of products.

ROLLER SMITH

Sales Representatives in all Principal Cities

ROLLER-SMITH

BETHLEHEM PENNSYLVANIA

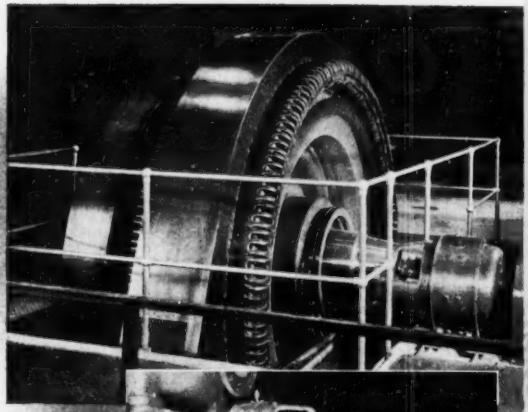
ELECTRICAL INDICATING INSTRUMENTS • AIRCRAFT INSTRUMENTS • SWITCHGEAR
AIR AND OIL CIRCUIT BREAKERS • ROTARY SWITCHES • RELAYS • PRECISION BALANCES

Elliott an important name

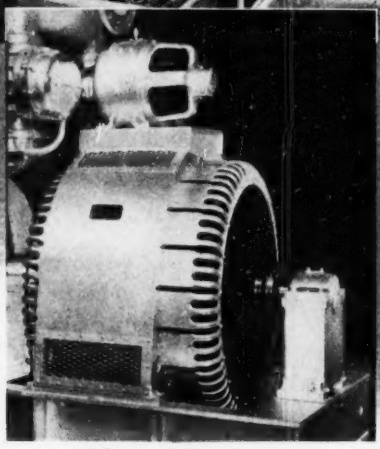
New FABRI-STEEL

MOTORS
for power house auxiliary drives

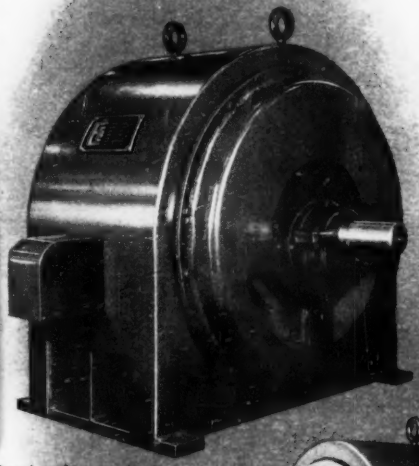
Write to Dept. ER for descriptive bulletins



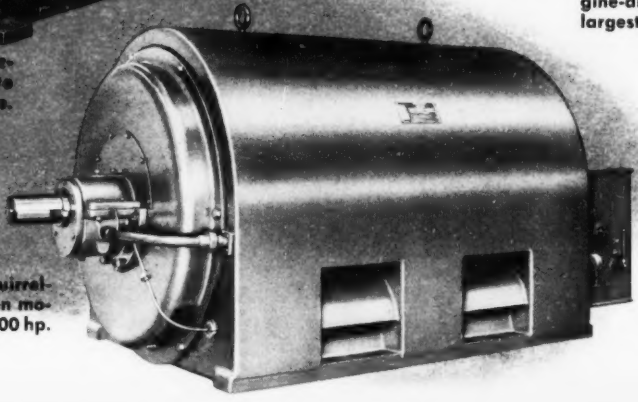
Low-speed Diesel or gas-engine-driven generators up to largest size engines available.



High-speed Diesel or gas-engine-driven generators up to largest size engines available.



Squirrel-cage induction motors 150 to 2000 hp, 4 to 14 pole.



Two-pole squirrel-cage induction motors 250 to 4000 hp.

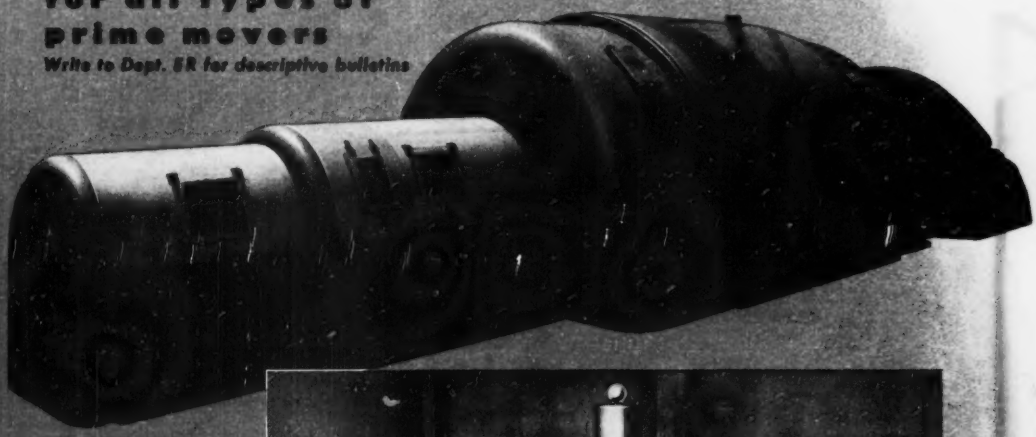
ELLIOTT COMPANY

RIDGWAY DIVISION
RIDGWAY, PA.

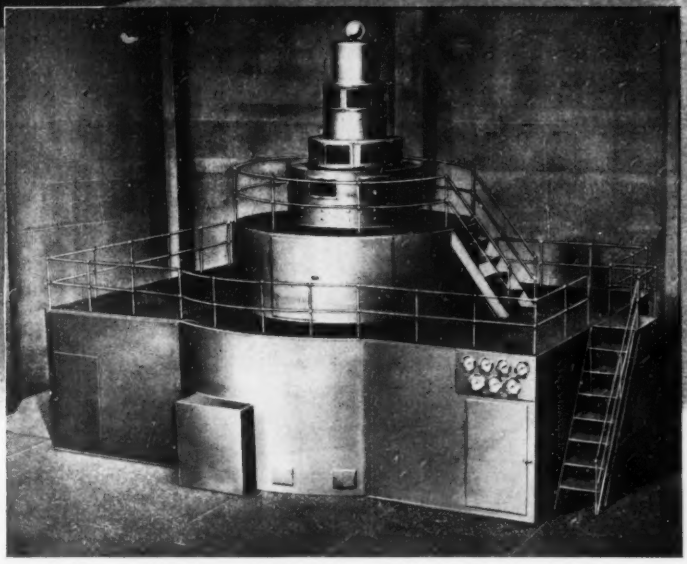
in America's electrical progress

FABRI-STEEL

GENERATORS
for all types of prime movers
Write to Dept. ER for descriptive bulletins



Steam- or gas-turbine-driven generators up to 20,000 kw.



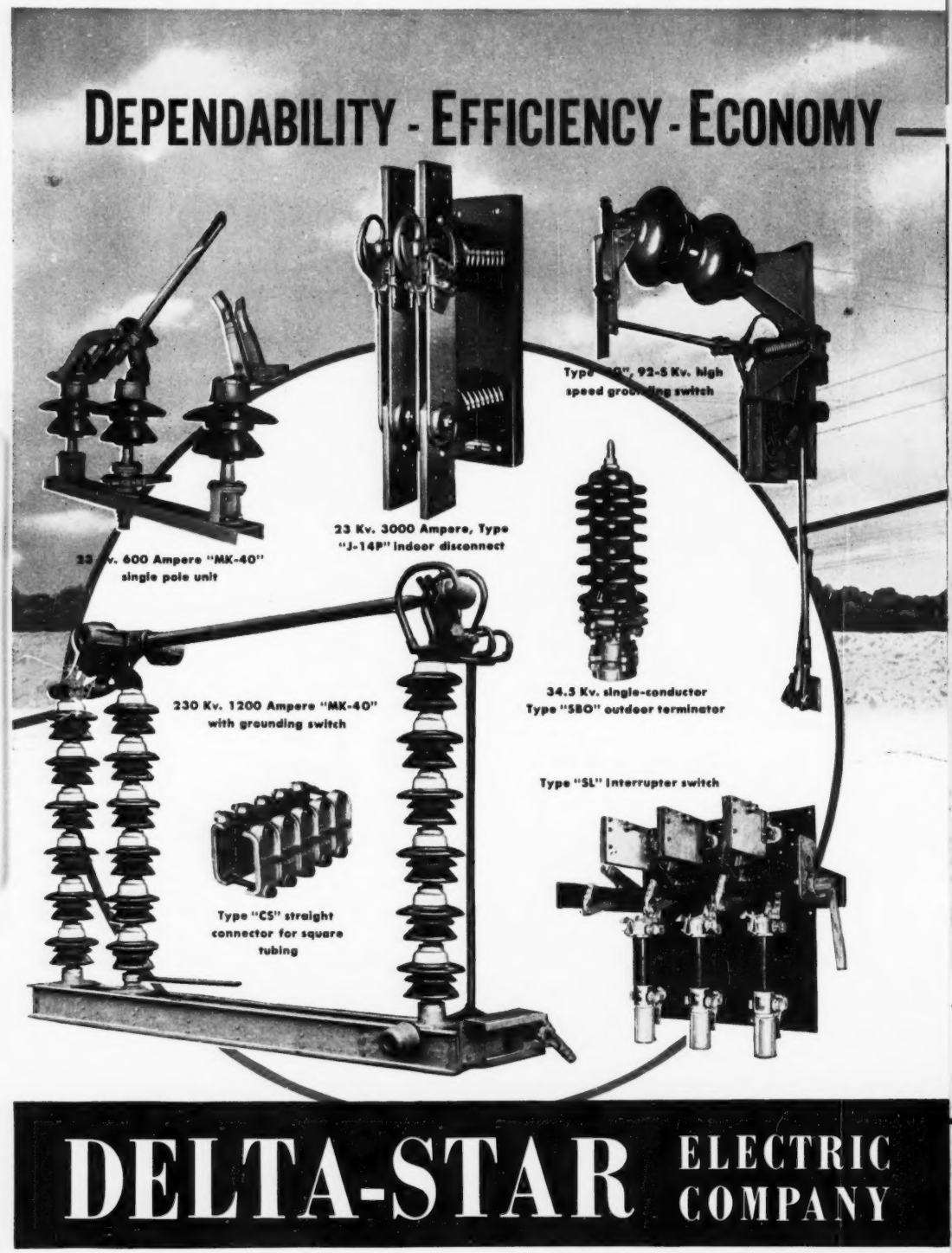
Hydraulic-turbine-driven generators up to 50,000 kva.

L-792

Plants at JEANNETTE, PA. • RIDGWAY, PA. • SPRINGFIELD, O. • NEWARK, N. J. • DISTRICT OFFICES IN PRINCIPAL CITIES

STEAM TURBINES • GAS TURBINES • GENERATORS • MOTORS • CONDENSERS • FEEDWATER HEATERS AND DEAERATORS • STEAM JET EJECTORS
CENTRIFUGAL BLOWERS • TURBOCHARGERS FOR DIESEL ENGINES • TUBE CLEANERS • STRAINERS • EXPANDERS • FILTERS

DEPENDABILITY - EFFICIENCY - ECONOMY —


23 Kv. 600 Ampere "MK-40" single pole unit
23 Kv. 3000 Ampere, Type "J-14P" indoor disconnect
Type "...", 92-5 Kv. high speed grounding switch
34.5 Kv. single-conductor Type "SBO" outdoor terminator
230 Kv. 1200 Ampere "MK-40" with grounding switch
Type "SL" interrupter switch
Type "CS" straight connector for square tubing

DELTA-STAR ELECTRIC COMPANY

In the final evaluation, the soundness of your power switching purchases will be measured not by the initial investment but rather by service rendered over the years.

Through more than four decades of experience in designing and manufacturing, plus constant research, Delta-Star has developed a complete line of power switching equipment with a long record of efficiency and economy.

This background of experience and reliability is your assurance that Delta-Star can best meet your requirements today and in the future.

DELTA STAR ELECTRIC CO. CHICAGO

MAIN OFFICE AND FACTORY — 2400 Block, Fulton St., Chicago 12, Ill. NEW YORK OFFICE — 140 Cedar St., New York 6, N. Y.

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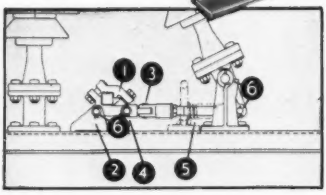
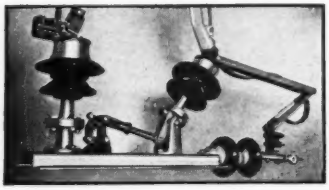
Washington, D. C.
Honolulu, Hawaii

CANADIAN ASSOCIATE
Canadian Line Materials Limited — Toronto 15, Canada

CHANCE Power

TYPE WN





TYPE VN

TYPE WN—VN
with the Independent Rockershaft

Chance Tilting Insulator Switches make positive contact on all phases because the Rockershaft operates independently of the tilting insulator. Not affected by angular distortion . . . each blade in a three-pole switch makes a complete contact without affecting the other two blades.

EASILY INSTALLED AND ALIGNED . . . Removable clamps (1) permit shaft to be laid in position after switch units are mounted. Rockershaft base (2) pivots to aid alignment with operating shaft. Pivot base and universal joint (3) compensate for warpage of supporting structure.

POSITIVELY NO SLAMMING . . . Special toggle joint (4) prevents slamming of blade when closing.

EXTRA LEVERAGE of Rockershaft gives smooth, easy operation with ample power to break ice accumulation. Bumper spring (5) cushions operating movement and helps start closing motion.

NO OILING . . . All working joints are fitted with Oilite bearings (6) for smooth, lifetime operation.

UNIVERSAL TERMINALS . . . Reversible switch terminal blocks accommodate cable ranging from No. 4 solid copper to 600,000 C. M. or ½" and ¾" I. P. S. tubing.

C491

C492

ABC INDUSTRIES

You know it's RIGHT

A. B. CHANCE COMPANY—CENTRALIA, MO.,

Switching Equipment

Side and Center Break
7.5 through 230 Kv.

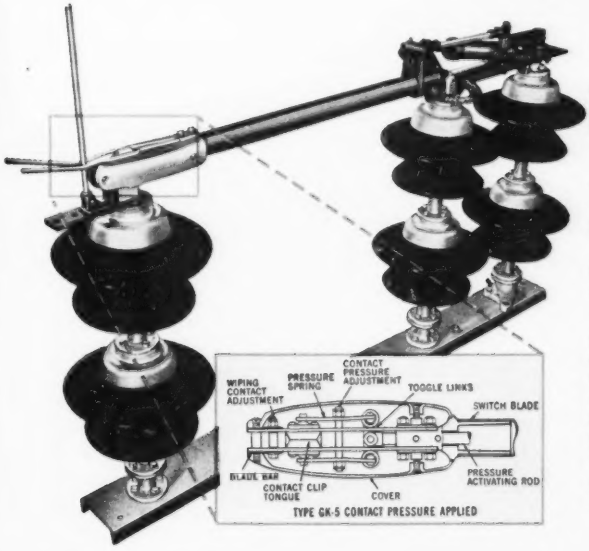
Designed primarily for use on installations where phase spacing or operating room is limited.

EASILY OPERATED . . . Insulator stacks, driven by crank and link mechanism, rotate in opposite directions to open the switch with a shearing action that easily breaks ice accumulations.

SILVER-INLAID, PROTECTED CONTACTS . . . Non-ferrous housing provides corona shielding and sleet protection for contacts. Heavily silver-plated blade produces low resistance contact. Contact springs, out of current path, maintain positive pressure.

Type XX Center Break Switches range from 46 through 230 Kv. Type X Side Break Switches range from 7.5 through 115 Kv. Both range from 400 through 1200 amps.

TYPE XX



TYPE GK-5 CONTACT PRESSURE APPLIED

TYPE GK-5
For Sub-Station and Line Disconnect Service up to 287 Kv.

LARGE AREA CONTACTS provide maximum thermal capacity.

SILVER CONTACT SURFACES maintain lower contact resistance by preventing copper oxidation.

CONTACTS WIPE CLEAN WITHOUT ABRASION . . . Blade and clip contacts engage with gentle wiping action that cleans surfaces without abrasion.

HIGH CONTACT PRESSURE APPLIED AFTER CLOSING . . . High pressure is attained between blade and clip by the final movement of operating mechanism. This pressure is attained without abrasive movement between blade and clip contact surfaces. Contact pressure is released *before* blade moves in opening operation.

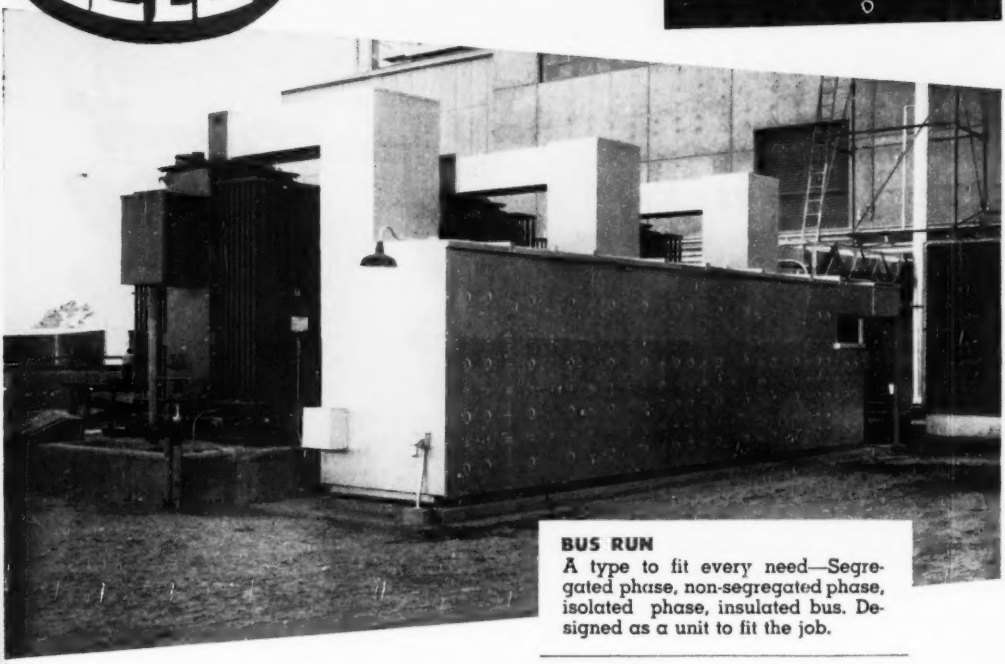
Diagram shows Type GK-5 contact mechanism. After closing motion is completed, cam-actuated control rod causes toggle links to expand against the leaf springs and transmit high pressure to the contact surfaces.

when you specify...

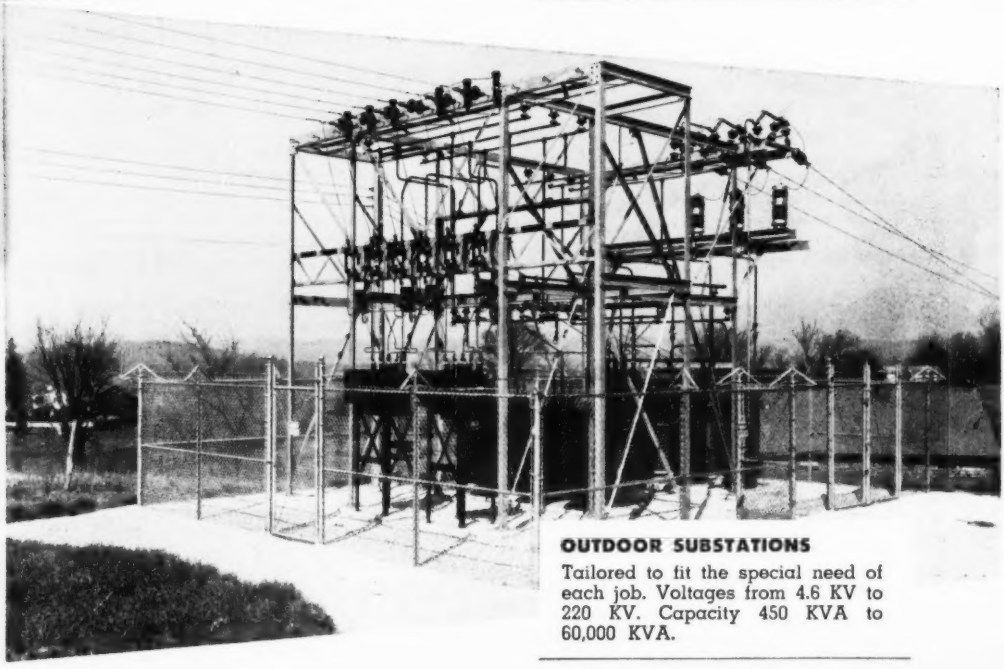
A·B·CHANCE CO.

SAN FRANCISCO, CALIFORNIA

ELPEQ products... the result



BUS RUN
A type to fit every need—Segregated phase, non-segregated phase, isolated phase, insulated bus. Designed as a unit to fit the job.



OUTDOOR SUBSTATIONS
Tailored to fit the special need of each job. Voltages from 4.6 KV to 220 KV. Capacity 450 KVA to 60,000 KVA.

# of 33 years of dependable service

to the electrical industry

● Satisfactory service to the electrical industry has been the aim of ELPECO ever since its founding in 1914. First activity was in the design and construction of outdoor substations.

This taught several important lessons. 1) Equipment should fit the needs of the particular job —and no two jobs are the same. 2) Costs should be kept low by eliminating frills. 3) Equipment performance must be improved.

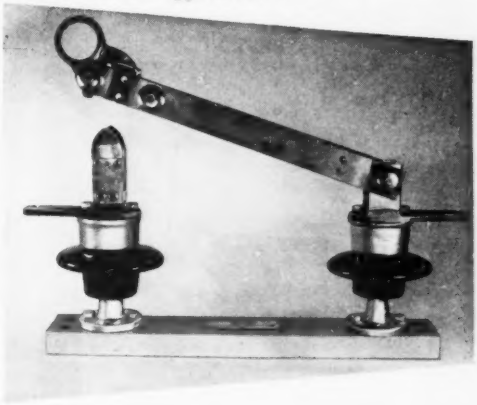
Looking for better answers Elpeco began to produce indoor and outdoor bus supports and disconnect switches. Recent developments in Elpeco switches are the simple and efficient Duo-Roll with high pressure contacts and the new Type V-STH line of hook stick operated switches with high pressure contacts. The latest Elpeco development is a low cost "Unitized" Bus Run that is designed, built and shipped as a complete unit—ready to install.

DUO-ROLL HIGH PRESSURE SWITCHES AIR BREAK DISCONNECTING

A complete line of switches with two high pressure contacts and permanent factory adjustment. Ratings from 7.5 KV to 161 KV; 400 Amperes to 4,000 Amperes. Horn Gap and Disconnecting types; upright, under hung or vertical mounted.

TYPE V-STH HIGH PRESSURE SWITCHES

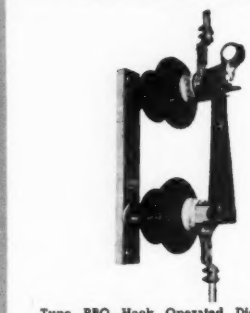
Hook stick operated disconnecting switches with high pressure contacts at both ends. Ratings from 7.5 KV to 161 KV; 400 Amperes to 3,000 Amperes. Parallel and truss type blades.



ELECTRIC POWER EQUIPMENT CORP.

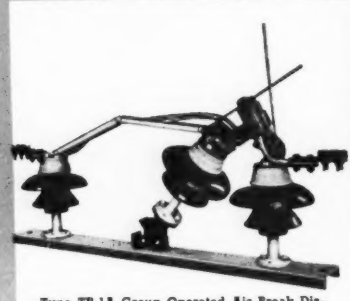
412 North 18th St. • Philadelphia 30, Penna.

33 Years of Progress.....



Type PBO Hook Operated Disconnecting Switch. 23 kv. 600 amp.

Type 57-A Group Operated Air Break Disconnecting Switch. 34.5 kv. 600 amp.

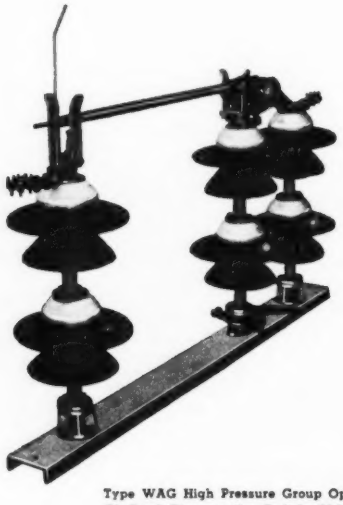


Type TR-1A Group Operated Air Break Disconnecting Switch. 23 kv. 600 amp.

SS A SYMBOL OF FOR 33

Southern States congratulates Electrical World on its 75 years of progressive and dependable service to the Electrical Industry.

We are proud to be a part of this great industry . . . and proud of the contribution we have made to it since our beginning thirty-three years ago. Originally formed for the purpose of repairing motors and transformers, Southern States has forged ahead during the past three decades until it now occupies a prominent place among the manufacturers of electrical transmission and distribution equipment. Many of the major



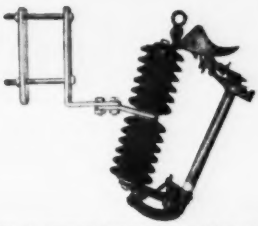
Type WAG High Pressure Group Operated Air Break Disconnecting Switch. 69 kv. 600 amp.

..1916-1949

DEPENDABILITY YEARS

developments in equipment, engineering and design were pioneered by Southern States.

It is in recognition of this progressive spirit and the constant dependability of its products that Southern States' equipment has been given preference on many of the country's leading power systems. Each item in the Southern States' line is engineered and manufactured to meet the most rigid specifications in its particular field and backed by Southern States' long-established standards for proven dependability.



Type 33 Dropout Cutout. 15 kv. 50 amp.

Type MH-2 Dropout Fuse. 46 kv. 100 amp.

Type HRHA-1 Fused Cap for Lightning Protection. 115 kv.

GROUP OPERATED AIR BREAK DISCONNECTING SWITCHES

HOOK OPERATED DISCONNECTING SWITCHES

AUTOMATIC SWITCHING CONTROLS AND EQUIPMENT

COMPLETE SUBSTATIONS

DISTRIBUTION CUTOUTS

EXPULSION POWER FUSES

FUSED GAP EXPULSION ARRESTERS

FUSE LINKS

POWER CONNECTORS AND FITTINGS

Southern States Equipment Corp.

HAMPTON GEORGIA

Representatives in:

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YOU CAN BE SURE.. IF IT'S

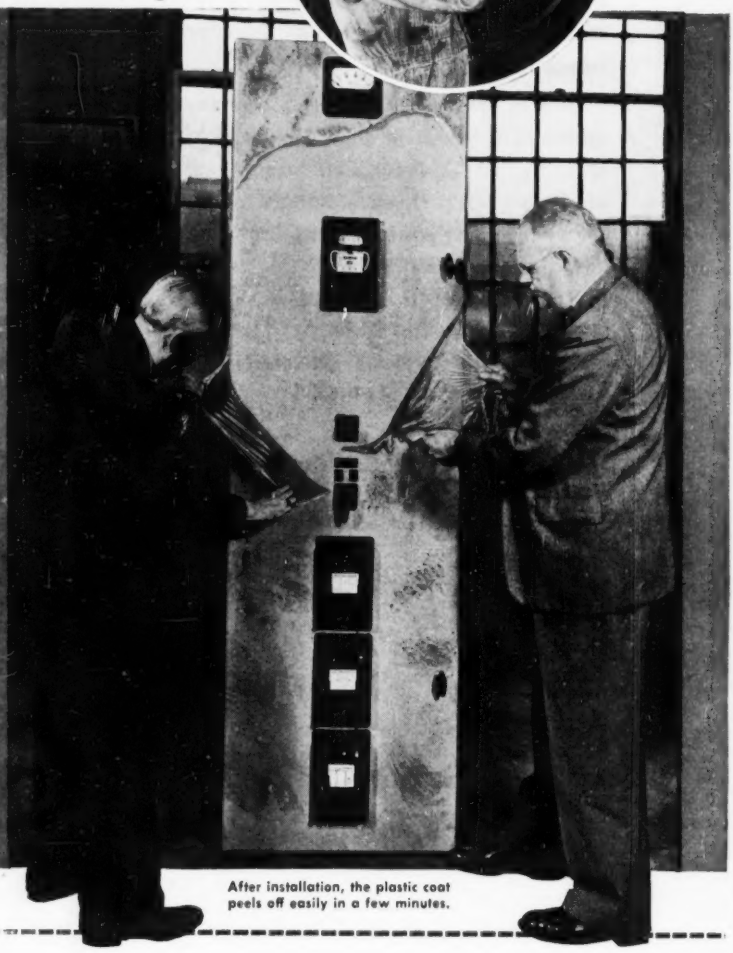
Westinghouse

IN 1947

Westinghouse provided All-Weather Undercoating... Lifetime protection for undersurfaces of *outdoor* switchgear

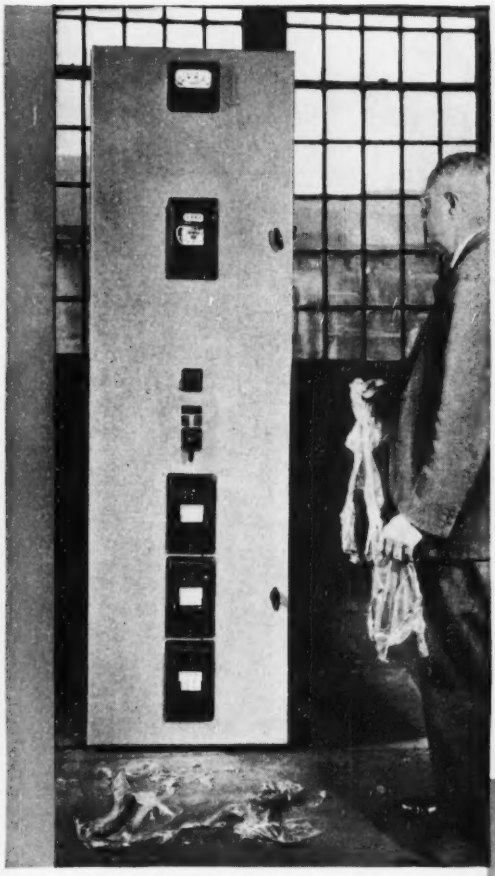
Plastic coating is sprayed on the switchgear panel before assembly, (not after final painting).

Unavoidable smudges and grease on this switchgear unit affect only the protective plastic coating.



After installation, the plastic coat peels off easily in a few minutes.

NOW... PLASTIC PROTECTION for Indoor Switchgear



Removal of the plastic coat reveals the original smart appearance of the switchgear unit.

Another Westinghouse Switchgear Feature

AT NO ADDED COST!

Dust, dirt and greasy fingerprints "peel off" switchgear units in a few minutes. The new plastic coating protects the smart appearance of metal-clad switchgear during shipping and installation. No longer is touch-up and repainting necessary to give your installation that "fresh-from-the-factory" appearance.

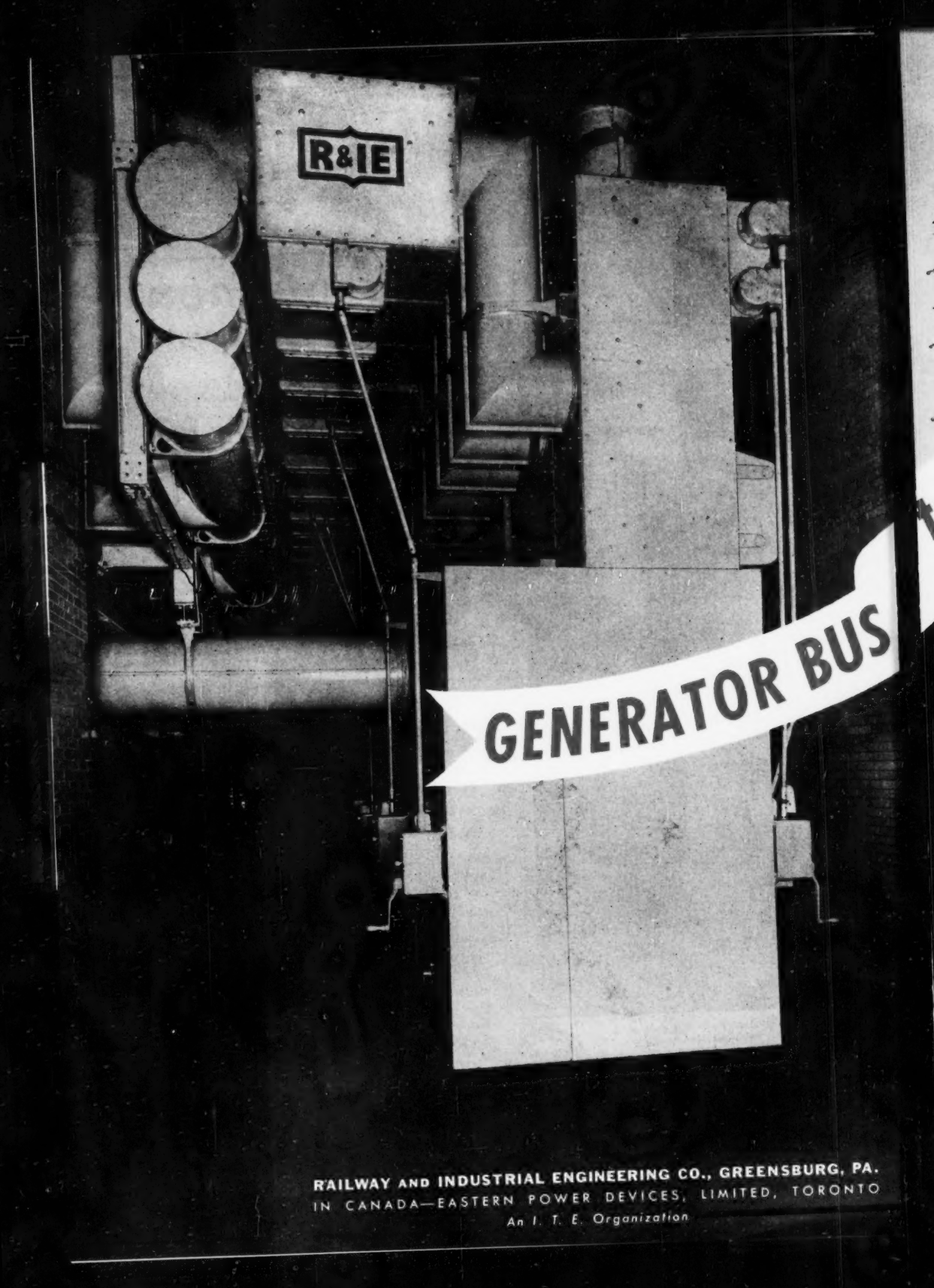
To give you this added benefit, Westinghouse employs a transparent plastic material. Sprayed on indoor metal-clad switchgear panels after final painting, it forms a tough protective coating that protects the finish through final assembly and wiring—and during shipment and installation. When the switchgear is ready for operation, simply "peel off" the plastic coat. Your installation then reveals the original factory finish. Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pennsylvania.

J-60689

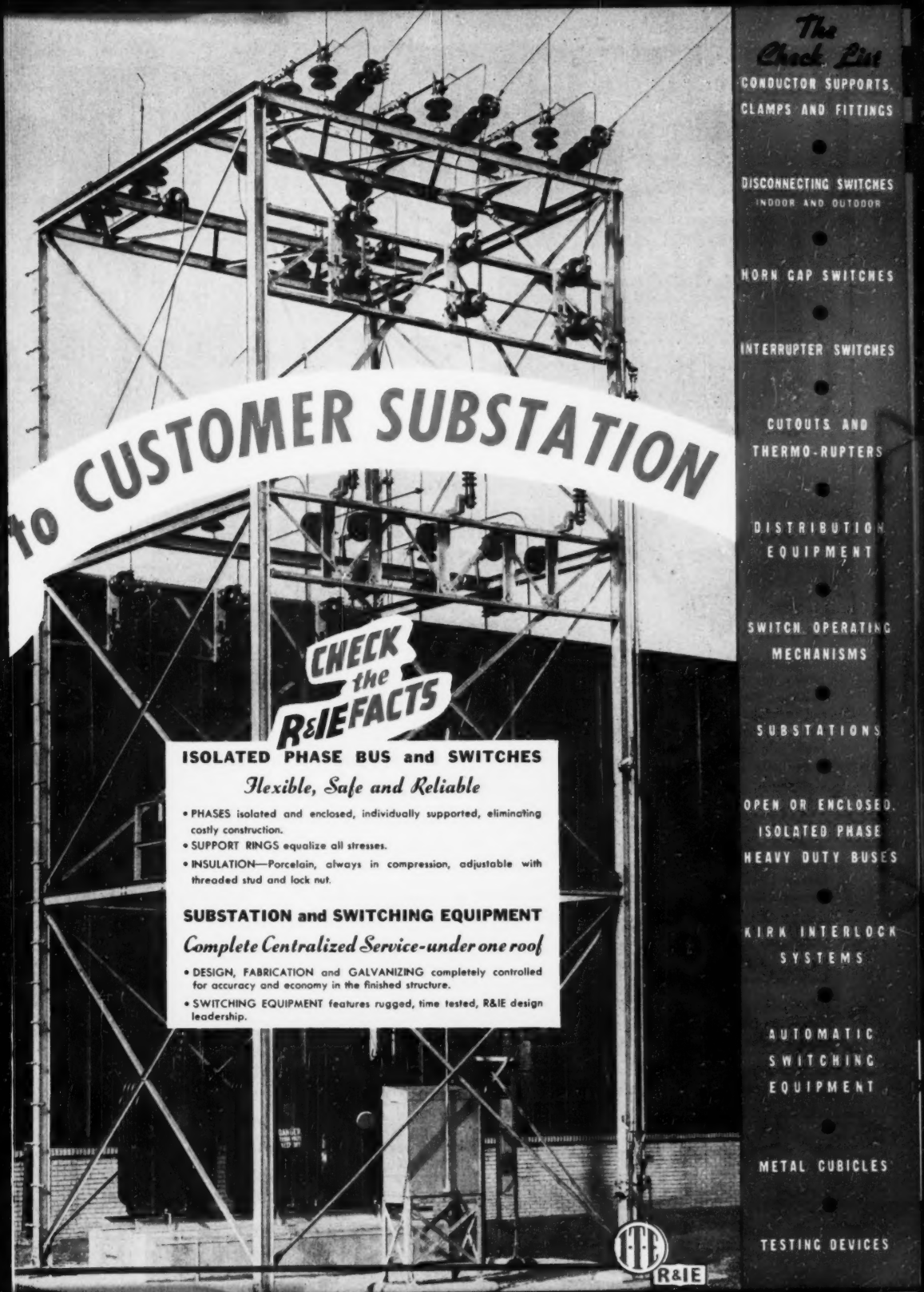
Westinghouse

METAL-CLAD SWITCHGEAR

FOR ANY SYSTEM



RAILWAY AND INDUSTRIAL ENGINEERING CO., GREENSBURG, PA.
IN CANADA—EASTERN POWER DEVICES, LIMITED, TORONTO
An I. T. E. Organization


to CUSTOMER SUBSTATION
CHECK the R&IE FACTS
ISOLATED PHASE BUS and SWITCHES
Flexible, Safe and Reliable
• PHASES isolated and enclosed, individually supported, eliminating costly construction.
• SUPPORT RINGS equalize all stresses.
• INSULATION—Porcelain, always in compression, adjustable with threaded stud and lock nut.
SUBSTATION and SWITCHING EQUIPMENT
Complete Centralized Service-under one roof
• DESIGN, FABRICATION and GALVANIZING completely controlled for accuracy and economy in the finished structure.
• SWITCHING EQUIPMENT features rugged, time tested, R&IE design leadership.
The Check List
CONDUCTOR SUPPORTS, CLAMPS AND FITTINGS
DISCONNECTING SWITCHES INDOOR AND OUTDOOR
HORN GAP SWITCHES
INTERRUPTER SWITCHES
CUTOUTS AND THERMO-RUPTERS
DISTRIBUTION EQUIPMENT
SWITCH OPERATING MECHANISMS
SUBSTATIONS
OPEN OR ENCLOSED, ISOLATED PHASE HEAVY DUTY BUSES
KIRK INTERLOCK SYSTEMS
AUTOMATIC SWITCHING EQUIPMENT
METAL CUBICLES
TESTING DEVICES
R&IE

NOW

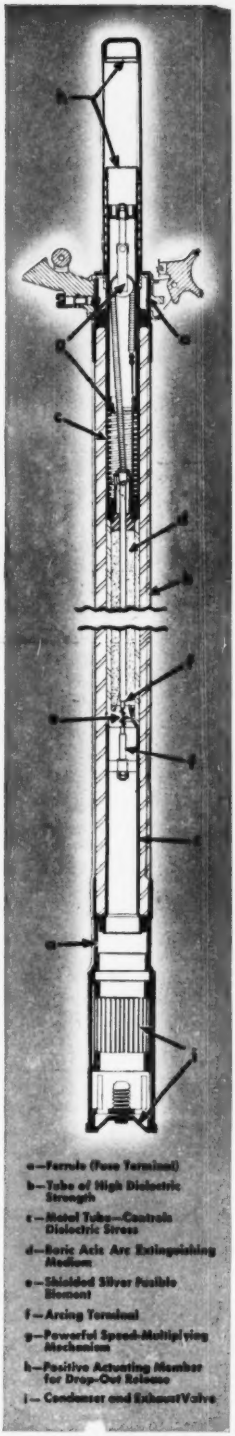
FULL COVERAGE

FUSE PROTECTION

at Transmission and Sub-Transmission Voltages

WITH

the SMD drop-out POWER FUSE


a—Ferrule (Fuse Terminal)
b—Tube of High Dielectric Strength
c—Metal Tube—Controls Dielectric Stress
d—Boric Acid Arc Extinguishing Medium
e—Shielded Silver Fusible Element
f—Arcing Terminal
g—Powerful Speed-Multiplying Mechanism
h—Positive Actuating Member for Drop-Out Release
i—Condenser and Exhaust Valve

● Establishing a new concept of dependability for fuses operating at higher voltages, the SMD Power Fuse affords *full coverage* protection. This means that this fuse provides for *prompt* isolation of faults in a positive, dependable manner under any and all of the following conditions:

1. Where high short circuit currents are encountered—possibly, for example, involving as high as 1,000,000 kva (3-phase basis, symmetrical current) for one fuse at 138,000 volts, or 2,300,000 kva for two fuses in series at 230,000 volts.

2. Where short circuit currents are of intermediate magnitude—and down to the lowest current which will melt the fusible element.

3. Where primary currents are of low value and low power factor—as in short circuits on the secondary of transformers.

4. Where the recovery voltage may be severe—as when primary fuses may have to clear secondary faults—particularly difficult where transformer banks operate with ungrounded primary neutral.

Full coverage protection also includes: (5) permanently accurate, reliable time-current characteristics and effective, prompt arc extinction, for coordinated isolation of faults and minimum system disturbance, and (6) electrical and mechanical characteristics which remain essentially unaffected by *corona*, weather, or atmospheric conditions over years of service.

The SMD Power Fuse has already had extensive laboratory and field tests, together with experience of a number of operations under service conditions. In field tests at 230,000 volts, short circuit values of 1,800,000 and 2,300,000 kva have been successfully interrupted in 3½ and 2½ cycles respectively.

It will benefit you to have full information on this remarkable development in power fuses. Ask for new Catalog Section 260 . . . NOW!

S&C ELECTRIC COMPANY 4421 Ravenswood Avenue Chicago 40, Illinois, U. S. A.

Formerly SCHWEITZER & CONRAD, INC.

Year After Year

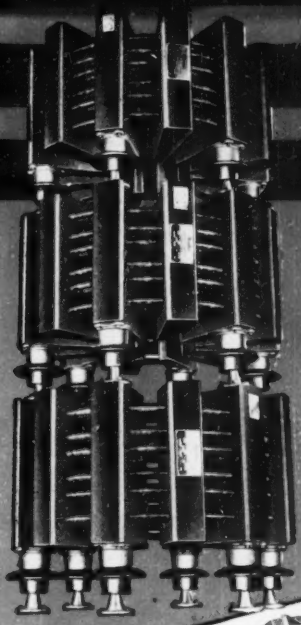
You Can Count On

Dependable Circuit Protection

WITH

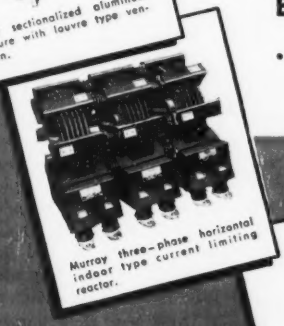
Murray

CAST-IN-CONCRETE
Current-Limiting Reactors

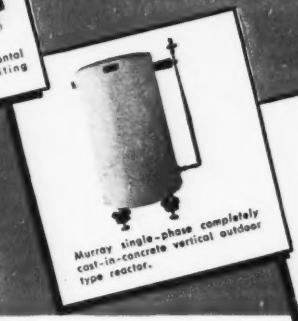


Typical Murray three-phase vertical outdoor type cast-in-concrete current limiting reactor.

Murray sectionalized aluminum enclosure with louvre type ventilation.



Murray three-phase horizontal indoor type current limiting reactor.



Murray single-phase completely cast-in-concrete vertical outdoor type reactor.

Murray pole top reactor.

Engineered to your specifications...
...for indoor or outdoor service.

- Feeder
- Generator
- Motor Starting
- Neutral Grounding
- Transformer Equalizing
- Special Purpose
- Station Tie
- Bus Tie
- Shunt

} Reactors

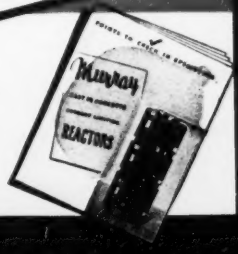
Murray

MANUFACTURING CORPORATION

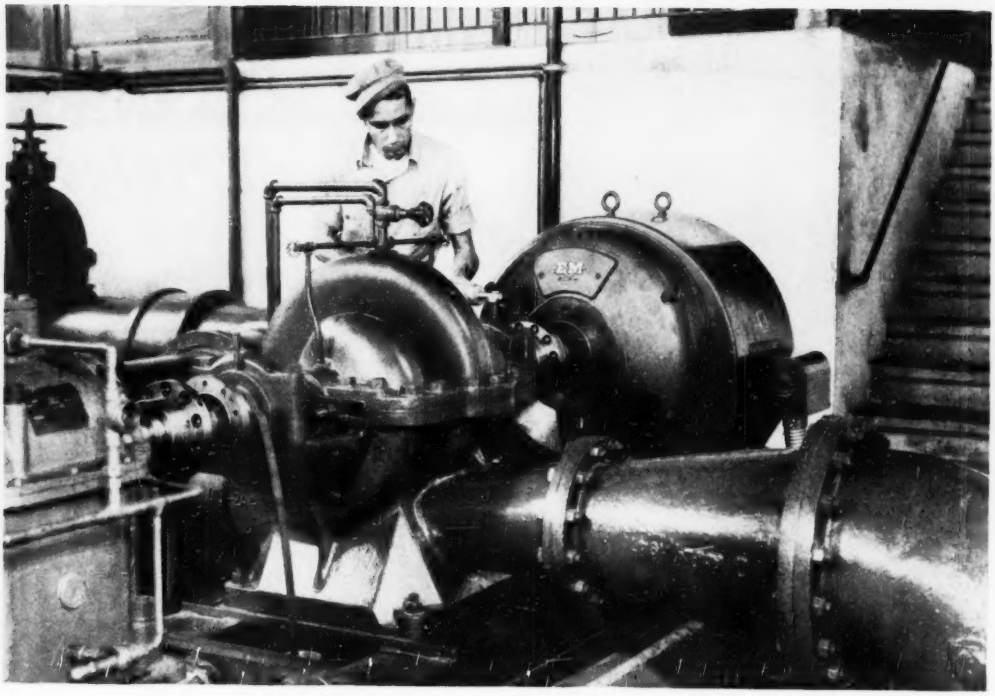
50 Years of Service to the Electrical Industry

1250 ATLANTIC AVENUE • BROOKLYN 16, NEW YORK

To help you give detailed information on reactors for your individual application, this comprehensive folder has been especially prepared. It provides a reliable guide to points to check in specifying all types of cast-in-concrete current limiting reactors. Write Murray for your copy today.



SERVICE ENTRANCE & METER EQUIPMENT • MAGNETIC CIRCUIT BREAKERS
SWITCHES • CURRENT LIMITING REACTORS • CROWS NEST AERIAL LADDERS



History repeats itself

WITH RESULTS OF GREATEST IMPORTANCE TO USERS OF HEAVY-DUTY INDUCTION MOTORS

Running with cool, quiet efficiency on some of industry's toughest jobs, E-M Heavy-Duty Squirrel Cage Induction Motors are furnishing on-the-job proof that there are differences in induction motors . . . in their reliability, economy, maintenance.

The development of these motors has been a case of history repeating itself . . . of bringing to the design and construction of induction motors the same kind of specialized large-motor creative engineering that has made Electric Machinery the headquarters for pacemaking developments in synchronous motors for nearly forty years. The long-lasting, quiet-running rotors of E-M Induction Motors, their wear-resistant, anti-friction or modern 1 to 1 ratio sleeve bearings; long-life, multi-layer insulation and job-engineered external protection are things that pay off in dependable and economical operation.

For example, the job-engineered protection of a drip-proof shield on the water pump motor shown above (400 h.p., E-M Induction Motor in Wichita plant of Kansas Water Company) eliminates any danger of damage and breakdown from dripping water or other falling material. Splash-proof and fully enclosed protection may also be obtained.

These great induction motors are the answer to the need for electric drives that can be relied on to serve long and well on the toughest, heavy-duty jobs. For full information, write for our publications 189 and 190.

ELECTRIC MACHINERY MFG. COMPANY
Minneapolis 13, Minnesota

1300-TPA-2083

E-M

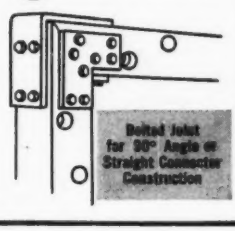
SPECIALISTS IN
BIG MOTOR ENGINEERING

MAKE CONNECTIONS THREE WAYS

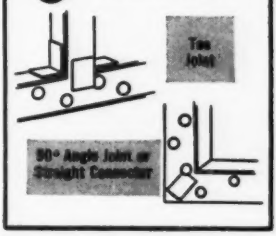
...with Chase Square Bus Conductors!

1 CLAMP TYPE JOINTS

2 BOLTED JOINTS



3 BRAZED JOINTS



THREE different types of connections can be used on installations of Chase Square Copper Bus Conductors—clamping, bolting or brazing. In addition, the four flat sides permit adequate and uniform pressure to be exerted between the large contact surfaces, resulting in firm, secure joints.

For information on other advantages of Chase Square Copper Bus Conductors, ventilated and unventilated, send for our new illustrated booklet to Dept. EW-59.

Chase

the Nation's Headquarters for
BRASS & COPPER

WATERBURY 20 CONNECTICUT

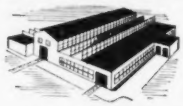
SUBSIDIARY OF KENNECOTT COPPER CORPORATION

THIS IS THE CHASE NETWORK . . . *handiest way to buy brass*

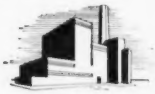
ALBANY† ATLANTA BALTIMORE BOSTON CHICAGO CINCINNATI CLEVELAND DALLAS DETROIT HOUSTON† INDIANAPOLIS KANSAS CITY, MO. LOS ANGELES MILWAUKEE MINNEAPOLIS NEWARK NEW ORLEANS NEW YORK PHILADELPHIA PITTSBURGH PROVIDENCE ROCHESTER† ST. LOUIS SAN FRANCISCO SEATTLE WATERBURY (†Sales Office Only)

Control enclosures and panels

fabricated by KIRK and BLUM

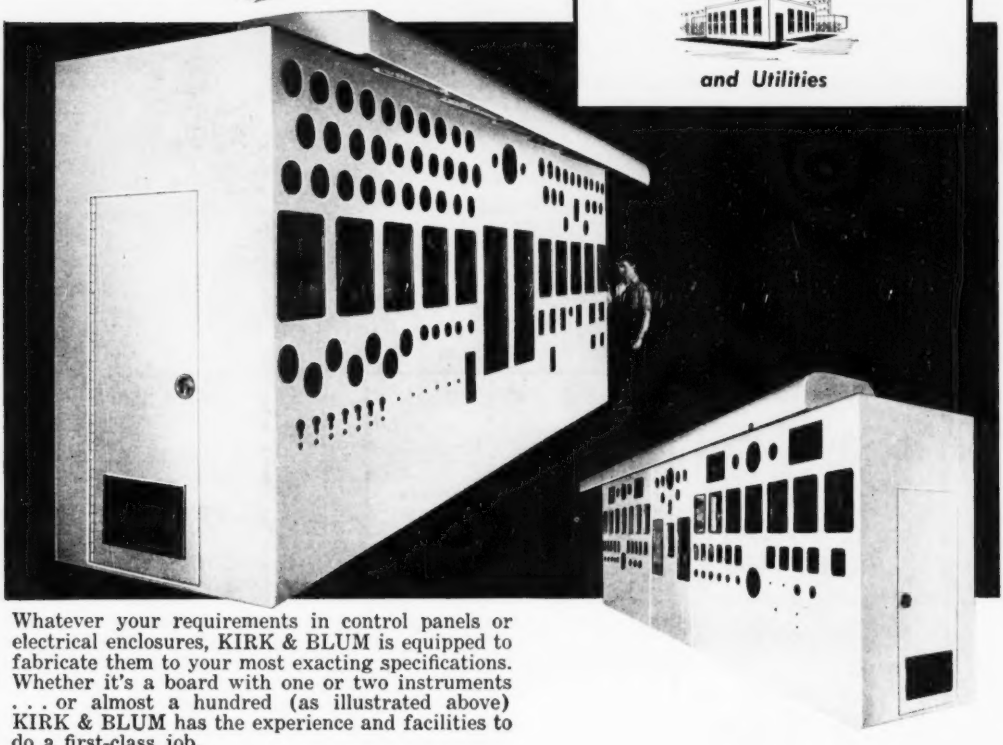


For Industry



Power Plants

and Utilities



Whatever your requirements in control panels or electrical enclosures, KIRK & BLUM is equipped to fabricate them to your most exacting specifications. Whether it's a board with one or two instruments . . . or almost a hundred (as illustrated above) KIRK & BLUM has the experience and facilities to do a first-class job.

The control panels above, constructed for an electrical machinery manufacturer, are 20′ and 28′ long, 8′—6″ high and 4′—8″ deep. The body of the panel is constructed of ¼″ steel plate, the light canopy above of ⅛″ steel.

KIRK & BLUM will gladly quote on your requirements . . . one or a thousand units . . . any size. Send prints and specifications to The Kirk & Blum Manufacturing Co., 2906 Spring Grove Ave., Cincinnati 25, Ohio.

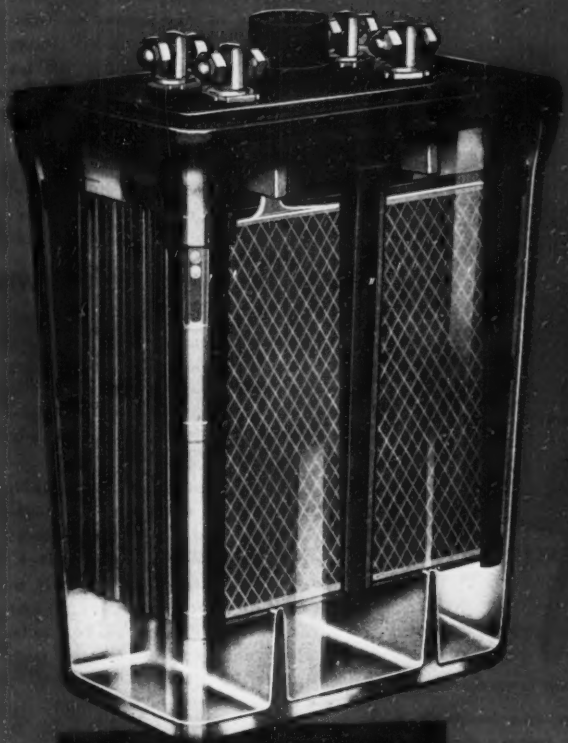
A free booklet, "Sheet Metal Assemblies" lists Kirk & Blum facilities for fabricating metals up to ¾". Write for your copy.

CONTROL DESKS and PANELS • SWITCH GEAR HOUSINGS • CUBICLES • TRANSFORMER HOUSINGS and TANKS • ELECTRICAL ENCLOSURES MACHINE BASES • VENTILATING LOUVRES

KIRK AND BLUM

ONLY GOULD Floté

GIVES YOU THESE TIME-TESTED FEATURES



1. **WEDGED ASSEMBLY**—another Gould "first." Corner locks, at points of greatest jar strength, maintain perfect plate alignment throughout battery life.
2. **SUPPORTED ELEMENT**—time-tested in the field. The element rests on lateral bottom supports which are molded into the tough Steel-Glass jar.
3. **MOLDED STEEL-GLASS JAR**—Tough, uniform in dimension, engineered to hold the element permanently in position. A time-tested Gould "first."
4. **BARRICADED OUTSIDE NEGATIVE PLATES**—Rigid, effective shields protect the element.
5. **SPRAYPROOF, LEAKPROOF COVER CONSTRUCTION**—Extra-deep cover seal, grid-tight post seal and sprayproof vent keep covers dry. You can install a Gould Floté near delicate instruments.
6. **POSITIVE PLATES SPECIFICALLY DESIGNED FOR FULL FLOAT SERVICE**—Extra heavy—⅞" thick. Exclusive Gould Floté grid alloy and grid design cut current consumption, increase life.

GOULD FLOTÉ

The only battery specially engineered for full float service—proved by 14 years of customer acceptance.

GOULD

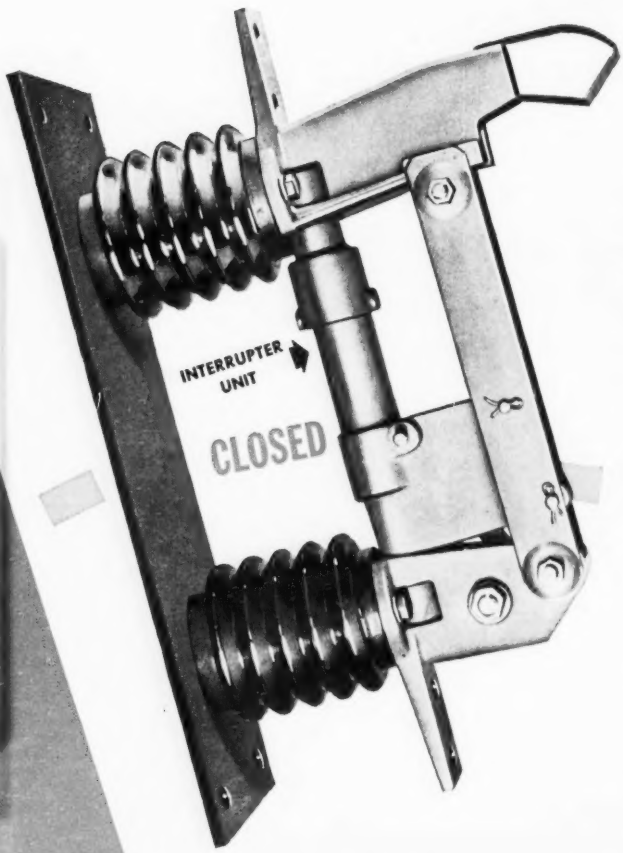
STORAGE BATTERY CORPORATION

TRENTON 7, NEW JERSEY

Always Use Gould Automobile and Truck Batteries

NEW AND UNIQUE

The THREE E Line of Indoo



Bulletin 141 covering this line of switches is now ready for distribution. Equipment is listed for hook stick and group operation, in combination with power fuses, and metal enclosed types. Send for it today.

The Electrical Engineers Equipment Co. conceived and pioneered the double blade type of disconnect switch. This style of switch is now used universally in the disconnect field. The ISOLATOR is another outstanding development resulting from Three E ingenuity and aggressive tactics.

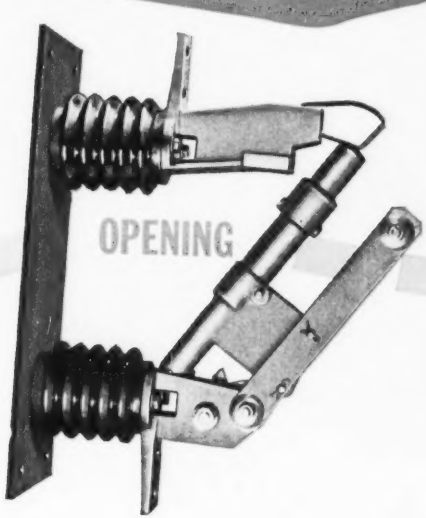
Pursuing a definite policy of continual improvement of equipment Three E announces another new contribution to high voltage switchgear.

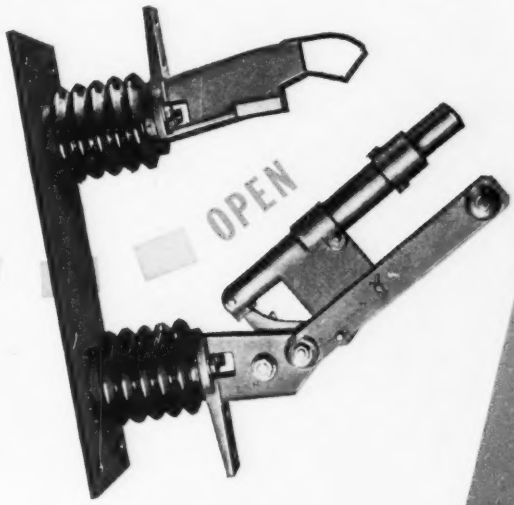
THE AIR INTERRUPTER SWITCH

This line of switches has been perfected after many months of designing, experimental manufacturing, laboratory and service testing. They are of the indoor type for voltages up to 15000, and can successfully interrupt currents up to 600 amperes.

The illustrations show a single element of a 15000 volt, 600 ampere, multi-pole, group operated, indoor air interrupter switch. View to left shows switch fully closed, but interrupter unit is not in circuit, all current being carried through main blades and contacts. The first movement of the control mechanism puts the interrupter unit in circuit and then the main contacts part. This condition is illustrated by the center view. This position is the point at which the interrupter unit is tripped, hence circuit is opened wholly inside the interrupter unit. THERE IS NO ARCING, NO BURNING OF CONTACTS, and gases are expelled through vents at top of interrupter tube. When switch is closed from its fully open position (see right-hand view) the interrupter unit automatically resets itself for the next opening operation.

Air INTERRUPTER Switches





HERE'S WHAT THIS LINE OF SWITCHES DOES

1. Switch load currents on feeders.
2. Switch load currents on transformers.
3. Sectionalize feeders and distribution circuits.
4. Interrupt primary magnetizing current of transformers.
5. Interrupt charging currents of lines and cables.
6. Interrupt exciting currents of feeder regulators.
7. Switch charging currents of capacitor banks.
8. Interrupt motor circuits.
9. Combined with power fuses, they provide a means of circuit interruption with overload and short circuit protection.
10. They eliminate the hazards caused by mistakingly opening high voltage circuits with ordinary disconnects.

ELECTRICAL ENGINEERS EQUIPMENT CO.
THREE
MELROSE PARK, ILL., U.S.A.
THE MARK OF QUALITY

ELECTRICAL ENGINEERS EQUIPMENT CO.

MELROSE PARK, ILLINOIS

BEST-the facts prove it!

6 reasons why Federal Noark Control Centers are best beyond doubt

FEDERAL NOARK CONTROL CENTERS give you an extraordinary and unequalled combination of advantages:

★ "Plug-In" starter units abolish working hot connections.

★ Silverplated busses and "plug-in" starter contacts backed up with spring steel reinforcements assure positive contact . . . prevent heating.

★ Guide rails provide accurate positioning of starter units for exact contact alignment . . . safe, easy handling when installing and removing units.

★ Starters, size 1 to 4, designed in multiples of a fixed dimension . . . afford maximum flexibility . . . permit complete rearrangements at least expense.

★ One size vertical section used for both front and back-to-back mounting.

★ Isolated cable troughs and vertical busses practically eliminate damage due to cable or other faults.

For superior engineering, flexibility, and installation ease, specify Federal Noark Control Centers. Write for full data and range of sizes. Federal Electric Products Co., 50 Paris St., Newark 5, N. J.

FEDERAL NOARK
CONTROL CENTERS

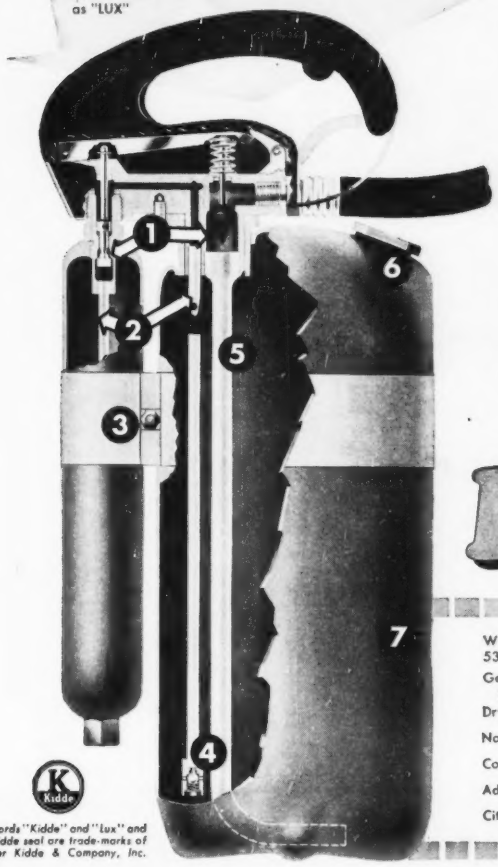
Complete line of Federal Electric Products includes Motor Controls, Safety Switches, Service Equipment, Circuit Breakers, Panelboards, Switchboards, Control Centers, Bus Duct ★ Sales offices in principal cities.

A New DRY CHEMICAL EXTINGUISHER WITH Trigger-Finger Control

(nothing new to learn)

Here, at last, is an extinguisher that's designed *right* to make the most effective use of an effective fire-extinguishing agent. *Kidde* Dry Chemical Extinguishers—made in 20- and 30-pound capacities—are operated simply by pulling a trigger—the same familiar, time-tested method used on all *Kidde** carbon dioxide (CO_2) extinguishers.

*Also known as "LUX"



PLUS these 10 other big features

1 *Simultaneous opening of CO_2 and powder valves.* No trapping of gas pressure in powder chamber *before* the discharge starts.

2 *Quicker transfer of pressure to powder chamber.* Siphon tube carries CO_2 to outlet in powder chamber, where it expands to a gas.

3 *CO_2 cartridge easily replaced.* Just loosen name band holding cartridge—then unscrew cartridge. Same size cartridge for both 20- and 30-pound extinguishers.

4 *CO_2 fluffs up powder—prevents packing.* Small port at bottom of CO_2 outlet tube allows gas to stir up powder.

5 *Powder discharges from top through siphon.* No danger of packing at hose connection.

6 *Powder filler cap needs no tools.* Unscrews easily for refilling of extinguishers in the field. Filler cap is safety-vented.

7 *Lightweight cylinder for ease of carrying.* Pound for pound, the *Kidde* Dry Chemical Extinguisher packs more fire-fighting punch!

8 *Better powder dispersion pattern.* Diffusion baffle in horn gives greater coverage, more effective application. No shut-off valve in horn to trap powder under pressure in hose. No rodding out of hose after use.

9 *Extinguisher tested for operation at* −40°F.

10 *Improved powder and packaging.* Powder specially processed to make it free-flowing; packed in weatherproof containers. 30-pound carton contains three 10-pound cans—for easy refilling of either 20- or 30-pound extinguishers. 50-pound containers also available.

Walter Kidde & Company, Inc.
530 Main Street, Belleville 9, N. J.

Kidde

Mail the coupon for full information.

Walter Kidde & Company, Inc.
530 Main Street, Belleville 9, N. J.

Gentlemen:

Please send me further information on the *Kidde* Dry Chemical Extinguisher.

Name.....

Company.....

Address.....

City.....State.....

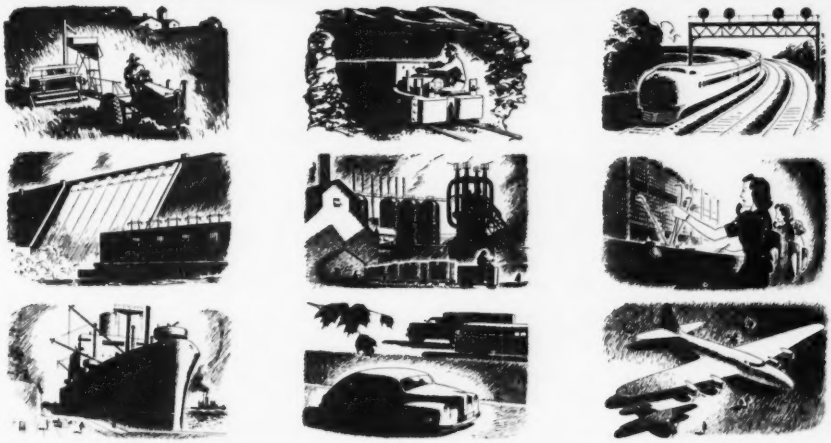
The words "Kidde" and "Lux" and the Kidde seal are trade-marks of Walter Kidde & Company, Inc.

GROWTH OF AN INDUSTRY

Exide

BATTERIES

1888...DEPENDABLE BATTERIES FOR 61 YEARS...1949



A capsule-size story of EXIDE BATTERIES and their contribution to modern industry...

ONLY six years after the first central station was put into operation, another electrical "first" took form in Gloucester, N. J. This was The Electric Storage Battery Company's first "accumulator," the great-granddaddy of the millions upon millions of Exide Batteries in use today.

In 1888, when The Electric Storage Battery Company was organized, the applications of storage batteries were only vaguely known. Much scepticism had to be overcome. As a result business developed slowly . . . a mere trickle at first. But when the storage battery had proved its worth, growth became rapid. The original building was soon inadequate and, in 1894, the company moved to its present site.

Before the turn of the century, Exide Chloride batteries were being widely used in Central stations, because they extended service from a few hours a day to around the clock. They soon became essential equipment in railway, telegraph and telephone service. They made possible the electric automobile and truck. All industry was aware of the possibilities of battery power. Then, just as the century ended, the first battery to bear the famous Exide name was produced . . . and a new era began.

Nearly every year of the twentieth century recorded a high spot in Exide history. A list of Exide "firsts" includes practically all the important applications of today. For there are Exides for every storage battery need . . . highly specialized types for individual applications . . . sizes that range from one that can be held in the palm of the hand to giant assemblies weighing many tons.

Exide Batteries provide safe, low cost power for battery electric trucks, mine locomotives, trammers and shuttle-cars. They are used by telephone and telegraph companies, radio and television stations. Railroads use them for car lighting, air-conditioning, Diesel locomotive cranking and signal systems. They are vital equipment in aircraft, ocean vessels, fire alarm systems, automotive vehicles, farm and off-the-highway machinery. They provide stand-by power for emergency lighting systems.

It's a long way from that small one-story building in 1888 to the large groups of factories, assembly plants, depots and operating departments with engineering field services located throughout the country. But Exide growth has been more than physical. Equal progress is to be seen in the improved quality of the product. For Exide's staff of engineers, chemists, technicians . . . the largest in the industry . . . seek continued improvement in product design and manufacturing control. Among the facilities at their command are the finest equipped laboratories of their kind.

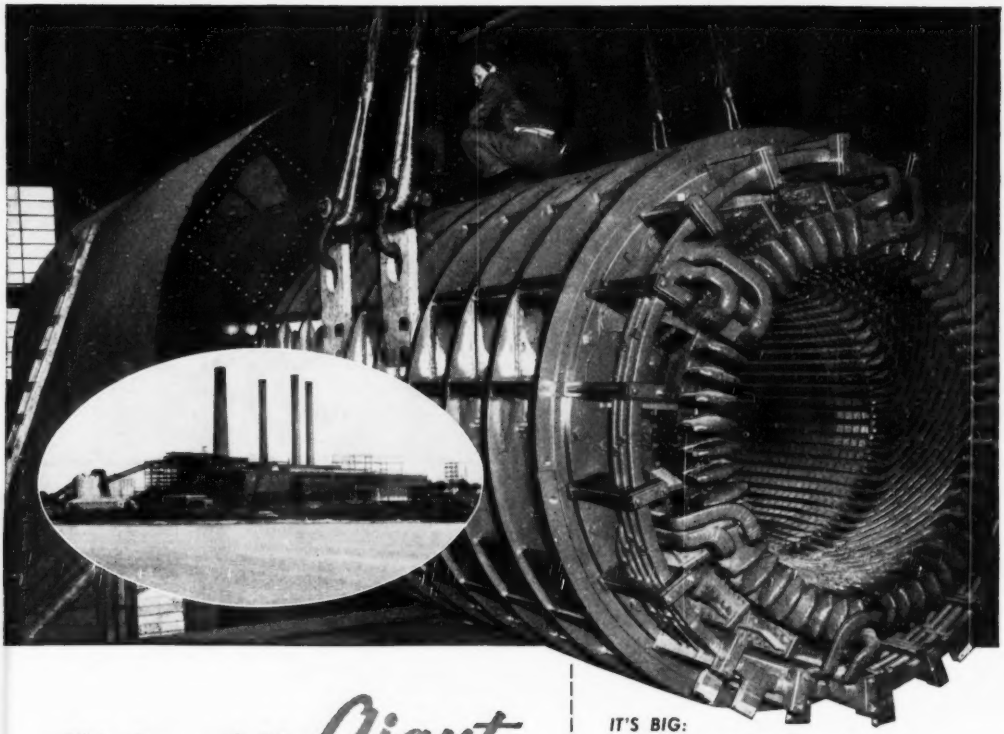
One of Exide's latest achievements is the Exide-Manchex Battery with its famous manchester positive plate. Among this battery's notable characteristics are extra long life, low maintenance cost, and increased power (watt) output per unit space. Because of its high one-minute rating, it is ideally suited for control bus and switchgear operation. The Exide-Manchex Battery also provides up to 100% more capacity in the same given space.

EXIDE-MANCHEX BATTERY

FOR CENTRAL STATION AND SUB-STATION SERVICE

"Exide" Reg. Trade-mark U. S. Pat. Off.

THE ELECTRIC STORAGE BATTERY COMPANY, Philadelphia 32 • *Exide Batteries of Canada, Limited, Toronto*



This Dependable *Giant* Helps Keep Industry Humming

IT'S BIG:

- The stator weighs 375,000 pounds.
- It rests on a concrete mat 14' thick.
- It's supported by 8 concrete pillars that extend 65' underground.
- The complete generator weighs 515,000 pounds.

Just installed at the Acme Plant of the Toledo Edison Company, this 100,000-kw turbine-generator, produced by Westinghouse Electric Corporation, will provide increased electrical energy for Toledo, Ohio, and its surrounding communities. To help assure *dependable operation*, this huge generator utilizes Fiberglas*-base Electrical Insulating Materials selected by Westinghouse to meet rigid performance specifications.

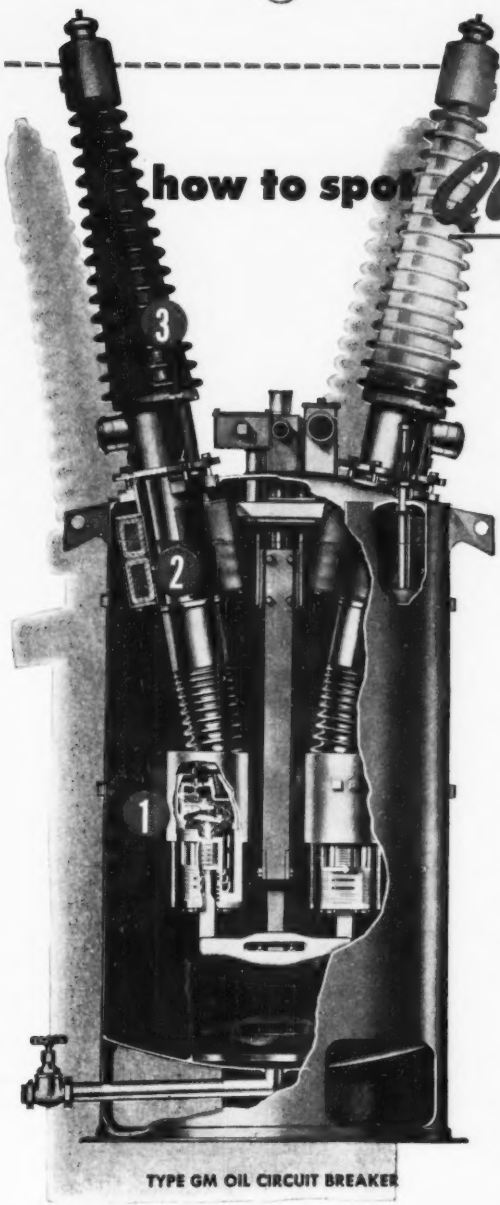
This installation, in a highly industrial area, is one of many examples of the wide usage of Fiberglas-base Insulations in the Electrical Industry. Fiberglas-base materials are available in the form of: Yarn, Cord, Braided Sleeving, Tape, Cloth, Mica Combinations, Varnished Cloth and Tape, Saturated Sleeving and Varnished Tubing, Laminates and Wire and Cable Insulations. For information on the complete line, write for your copy of the "Fiberglas-base Electrical Insulating Materials" Manual. Owens-Corning Fiberglas Corp., Textile Products Division, 16 E. 56th St., New York 22, N. Y. In Canada: Fiberglas Canada Ltd., Toronto, Ontario. Cable address: "Fiberglas", Toledo, Ohio, U.S.A.

OWENS-CORNING
FIBERGLAS
ELECTRICAL INSULATING MATERIALS

*FIBERGLAS is the trade-mark (Reg. U. S. Pat. Off.) of Owens-Corning Fiberglas Corporation for a variety of products made of or with glass fibers.

YOU CAN BE **SURE**.. IF IT'S

Westinghouse



TYPE GM OIL CIRCUIT BREAKER

how to spot *QUALITY* in a power circuit breaker

Here is the inside story of speedy, reliable circuit breaker operation. It's the reason why Westinghouse Type GM Circuit Breakers provide shorter arcing time, reduced arc energy, lower maintenance, longer life.

1. Multi-flow "De-ion" grids provide efficient arc interruption. Pressure generated in short, upper arc drives oil to extinguish lower arc—quickly.
2. Bushing-type current transformers, or linear couplers, provide reliable relaying and bus differential protection—with no additional space requirements.
3. Type "O" condenser bushings combine high mechanical, electrical and thermal strength. Complete impregnation and uniform voltage distribution insure extremely low losses.

These are a few of the reasons why you'll get better service continuity and greater system stability with the Westinghouse Type GM Oil Circuit Breaker. Ask your near-by Westinghouse representative for complete details and booklet B-4012. Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pa.

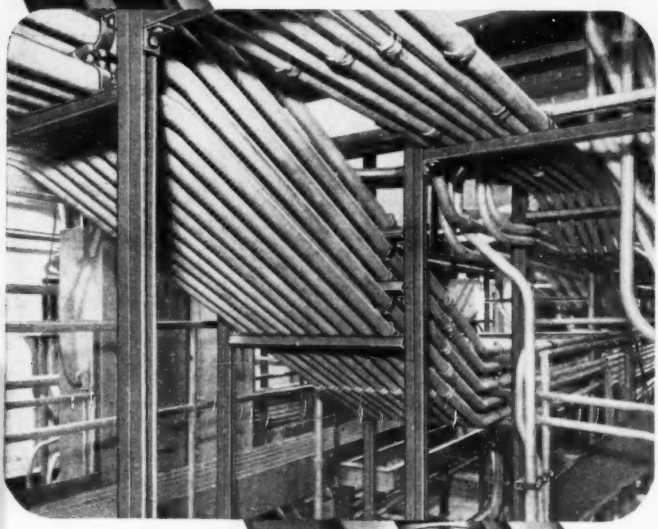
J-60712

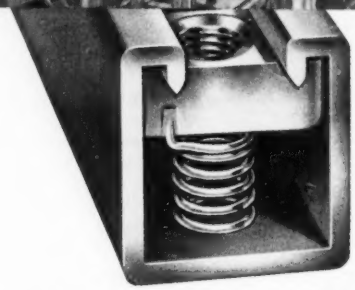
Westinghouse

POWER CIRCUIT BREAKERS

Conduit Racking Made Easy!

An ordinarily difficult job made easy with versatile Unistrut channel, fittings and clamps. Bends, turns and adjustments quickly accommodated through Unistrut's unusual flexibility.





They did it with **"UNISTRUT"** ALL-PURPOSE METAL FRAMING

You also can quickly, easily and economically build all types of shelving, framing, supports, mounts, racks, tables and benches—pipe and cable hangers, and fluorescent fixture supports—and many other structures with only a hacksaw and wrench.

Here's real "strength without bulk." Completely adjustable and reusable. Unistrut is steel channel with a continuous slot. You simply insert the Unistrut spring nut at approximate point where you wish to attach another framing member, slide to exact position, bolt and tighten. No drilling or welding required.

Unistrut gives flexibility and installation advantages that can't be attained by old-fashioned methods of frame construction.

ALL PURPOSE UNISTRUT METAL FRAMING

Write for Bulletin No. 37

PRODUCTS COMPANY

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Representatives in Principal Cities.

Fifty Years of Electrical Engineering

An Editorial in ELECTRICAL WORLD
July 7, 1934

"Last week electrical engineers celebrated the fiftieth anniversary of the American Institute of Electrical Engineers. Pioneers of the early days, engineers on the present firing lines, educators and junior engineers who look to a professional future joined to celebrate the glorious record of accomplishment, of tradition, and of service established by the profession in its relatively short life. The institute has acted as the storehouse for knowledge, as the forum for discussion and education and symbol for professional ideals.

"We congratulate the institute upon its record and are glad to join with the electrical industry in celebrating this fiftieth anniversary. We have faith in the industry and the profession and believe the future will bring forth new names to place with those of Weston, Edison, Sprague, Steinmetz, Lamme, Carty, Thomson and others to stand for those ideals and accomplishments that made the present celebration so glorious. The institute will continue to be the lighthouse on the course to the professional haven of the future."

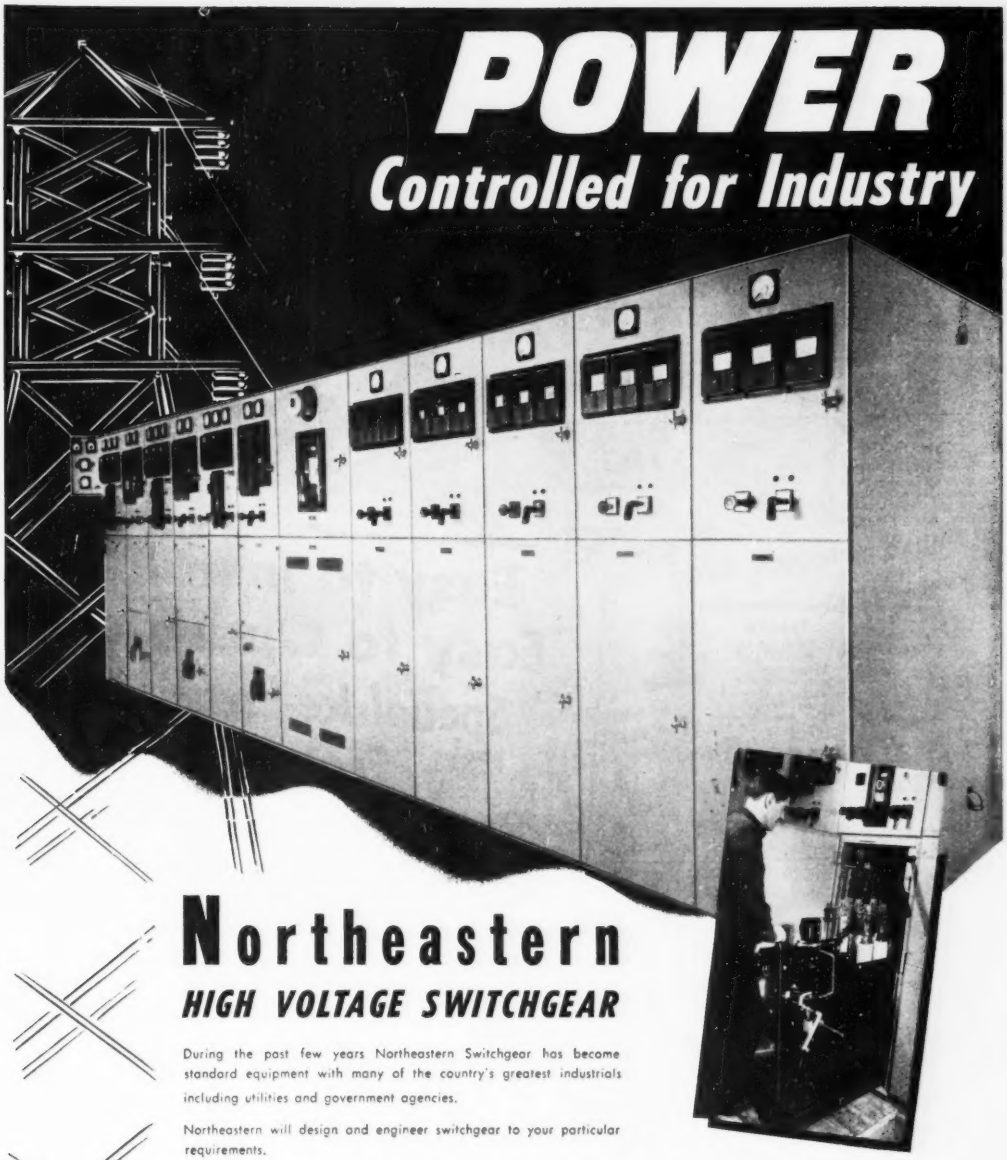
Hartford's New Mercury Boiler

An Editorial in ELECTRICAL WORLD
March 29, 1947

"Hartford Electric Light's decision to replace its South Meadow mercury boiler with a new one and to revamp the present mercury turbo-generator signifies the company's confidence in this process.

"The economies of the mercury vapor process, when articulated with steam units, are now well known to the industry. It suffices to say that this latest program, involving approximately $2,000,000, can be counted on to save over $300,000 yearly in fuel. It will enable the company to operate two of its 20,000-kw. steam-turbine units at full rating. Service Reliability, often questioned by engineering skeptics, has met the stiff requirements of the day. The program illustrates afresh the far-reaching scope of modern fuel-burning plant developments.

POWER
Controlled for Industry



Northeastern
HIGH VOLTAGE SWITCHGEAR

During the past few years Northeastern Switchgear has become standard equipment with many of the country's greatest industrials including utilities and government agencies.

Northeastern will design and engineer switchgear to your particular requirements.

Write today for your copy of Northeastern's new handbook on switchgear and control centers.

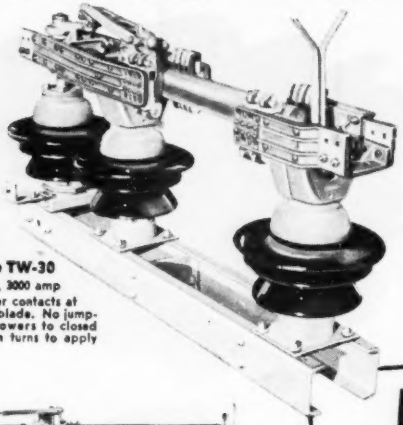
7,500 Volt vertical lift switchgear with 50,000 KVA oil circuit breaker

NORTHEASTERN ENGINEERING, INC.

MANCHESTER, NEW HAMPSHIRE

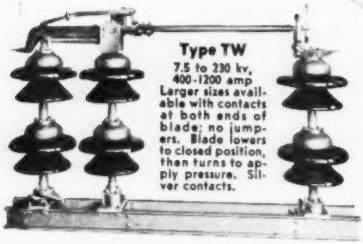
Outdoor High-Voltage
SWITCHES
7.5 to 230 kv

Disconnecting, Sectionalizing, By-passing, Grounding



Type TW-30
7.5 to 34.5 kv, 3000 amp
Multiple silver contacts at both ends of blade. No jumpers. Blade lowers to closed position, then turns to apply pressure.

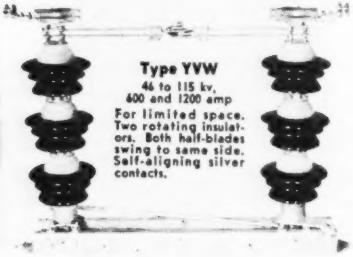
Type SW
7.5 to 34.5 kv, 400 and 600 amp
46 kv, 600 amp
Tilting insulator. Floating adjustable high-pressure roller silver contacts. Type SWA similar, but with two insulators per pole.



Type TW
7.5 to 230 kv, 400-1200 amp
Larger sizes available with contacts at both ends of blade; no jumpers. Blade lowers to closed position, then turns to apply pressure. Silver contacts.

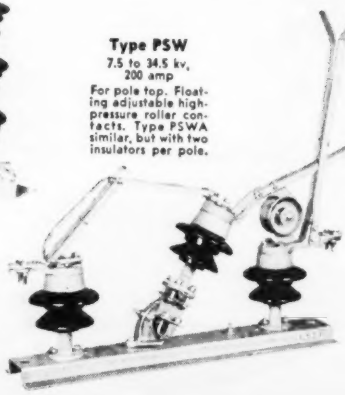
Easy to Install, Easy to Operate, Special Ice-breaking Features

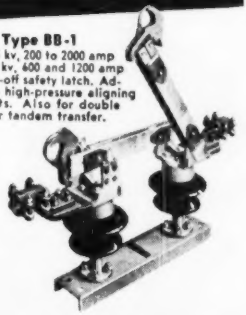
Upright, vertical, or underhung mountings for three- or six-pole group operation (except Type BB-1).



Type YVW
46 to 115 kv, 600 and 1200 amp
For limited space. Two rotating insulators. Both half-blades swing to same side. Self-aligning silver contacts.

Type PSW
7.5 to 34.5 kv, 200 amp
For pole top. Floating adjustable high-pressure roller contacts. Type PSWA similar, but with two insulators per pole.





Type BB-1
7.5 to 34.5 kv, 200 to 2000 amp
46 and 69 kv, 600 and 1200 amp
Has pry-off safety latch. Adjustable high-pressure aligning contacts. Also for double throw or tandem transfer.

43 Years of Specialized Experience

For 43 years the Pacific Electric Mfg. Corporation has specialized in the design and manufacture of high-voltage switching equipment. Major types of air-break switches are shown here. Other outdoor equipment includes oil circuit breakers, fuse cutouts and bus fittings.

All through the years, repeat orders from power companies everywhere testify that this equipment is properly engineered for the job.

Switches shown are single-pole units for group-operation by mechanism, except Type BB-1 which is hook-operated. All outdoor type. Mounted on rigid bases for perfect alignment. Nonferrous current-carrying parts. NEMA and AIEE Adopted Standards.

Get All Facts . .

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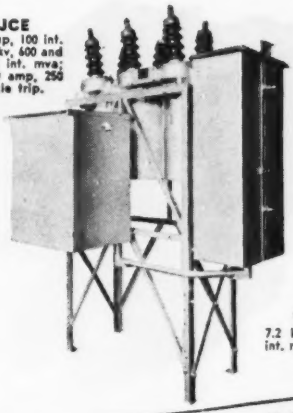
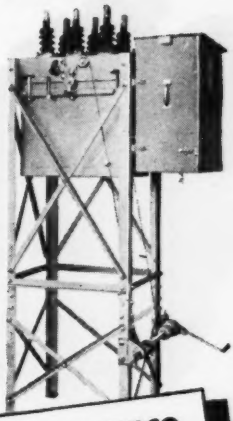
OIL CIRCUIT BREAKERS

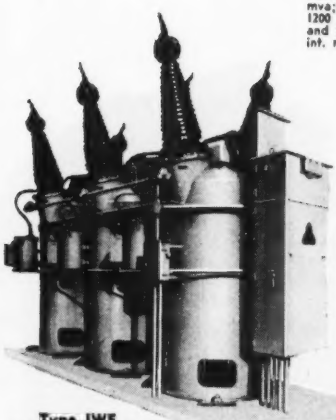
for Outdoor High-Voltage Stations . . .

Type JCE
14.4 kv, 400 amp, 100 int. mva; also 14.4 kv, 600 and 1200 amp, 250 int. mva; and 23 kv, 600 amp, 250 int. mva, 8-cycle trip.





Type AKE
7.2 kv, 600 amp, 50 int. mva, 8-cycle trip.



Type JWE
115 kv, 800 amp, 1500 int. mva, 5-cycle trip.

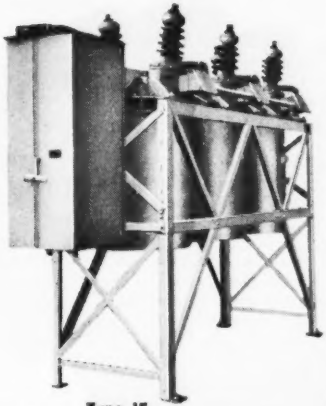
Reliability and Low Maintenance

All Pacific breakers, large and small, embody the **same** time-tested design elements:

(1) **Motor-Compressed-Spring Stored-Energy Operating Mechanisms** assure identical opening and closing times, regardless of frequency of operation.

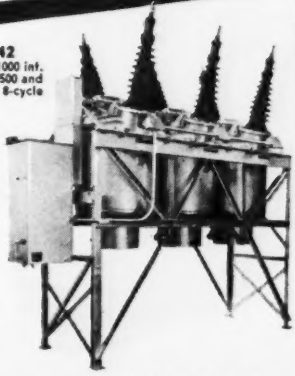
(2) **Arc-Expulsion Chambers** with directed gas blast extinguish arcs without appreciable rise of tank pressure or burning of contacts.

(3) **Sliding Shoe Contacts** with **Leaf-Type Pressure Springs** eliminate stress on bushings, require no sensitive adjustment to maintain pressure or fix closed position. Wiping action reduces pitting. Restrikes reduced because contacts separate only when traveling at high speed.



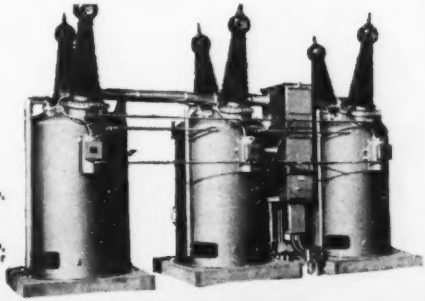
Type JE
23 kv, 1200 amp; 34.5 kv, 600 amp, both 500 int. mva; and 34.5 kv, 1200 amp, 1000 int. mva; also 46 kv, 600 amp, 500 int. mva, and 1200 amp, 1500 int. mva, 8-cycle trip.

Type JE-42
69 kv, 600 amp, 1000 int. mva; 1200 amp, 1500 and 2500 int. mva, 8-cycle trip.



Type RWE
115 kv, 138 kv, and 161 kv, 1200 amp, 3500 int. mva, 5-cycle trip.

Type RHE
Is similar, for 138 to 230 kv, 800 amp, 5000 int. mva; or 1200 amp, 7500 or 10,000 int. mva, 3-cycle trip.



AIEE and NEMA Standards

Get All Facts . .

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Other Representatives in Principal Cities

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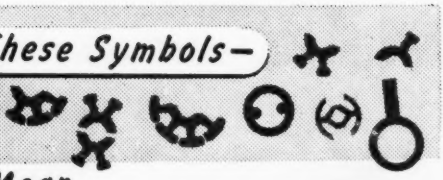

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INFINITE VARIETY IN ELECTRIC SWITCHING

They are the shapes of the standard contact elements used in ESCO multi-pole, rotary, detent switches. These elements, specially assembled to meet your particular switching requirements, permit a single control handle to operate a multi-pole, multi-stage, multi-position switch.

An infinite variety of circuit sequences can be obtained by proper assembly of the contact terminals, rotor blades, detent plates, and frame elements of which ESCO multi-pole, rotary, detent switches are composed. Whatever the control function you require . . . it can be obtained with an ESCO switch.

THESE SPECIFICATIONS
cover wide operating needs

RATINGS	10A, 125 VAC — 5A, 250 VAC
POLES	One to 40
POSITIONS	4, 8, or 16
HANDLES	Oval, pistol-grip, removable
MOUNTINGS	Base or panel
CONNECTIONS	Side

COST . . . below that of most "standard" switches.

Write today for data sheets showing the structural details that provide ESCO'S unsurpassed versatility.

PROMPT DELIVERY

For your heavy-duty applications, specify ESCO rotary snap switches . . . available in current ratings up to 200 amperes at voltages up to 460 a-c.

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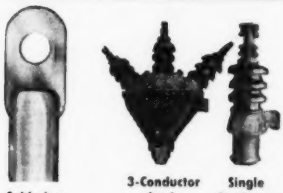

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give you safer cell structures

CELL STRUCTURES built with J-M Trancell provide greater safety for station operators... give adjacent equipment greater protection against heat transmission. The reason—J-M Trancell is completely fireproof, rotproof and rustproof . . . is erected entirely *without* water to form a *dry* housing that guards against shorts.

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Basically asbestos, J-M Trancell Materials are available in a wide variety of types and combinations to meet every requirement of high-voltage service. You can order Trancell pre-cut to your special dimensions . . . or have it cut by your own maintenance department thereby saving shut-down time, detail drawings, and materials. For complete information, write Johns-Manville, Box 290, New York 16, New York.

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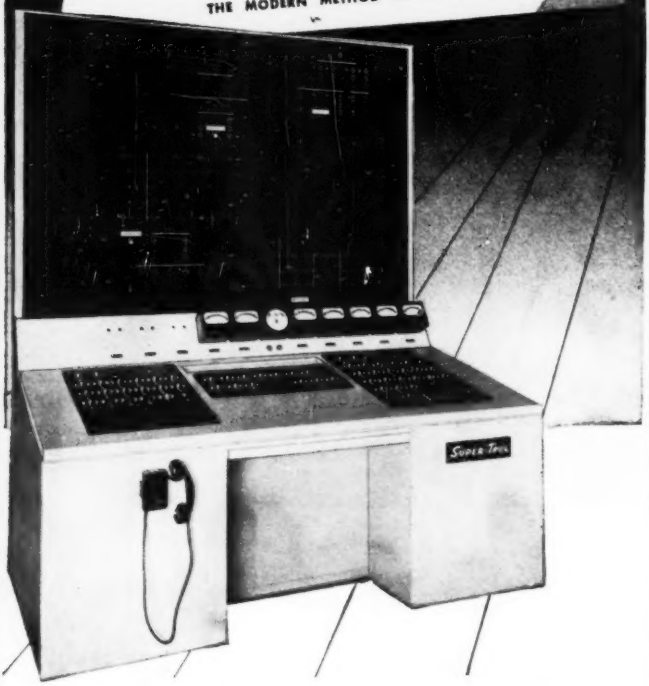
for housing electrical equipment

fast accurate control at your fingertips with SUPER-TROL

THE MODERN METHOD OF SUPERVISORY CONTROL



SUPER-TROL is today's answer to remote and continuous equipment control requirements in sub-stations . . . hydro-plants . . . pumping stations . . . and the numerous other places needing remote control.

PROVIDES FAST FINGERTIP CONTROL

Throwing a switch and pushing a button starts a generator . . . closes or opens a breaker . . . cuts out a transformer . . . meters voltage, current, or power at any point. SUPER-TROL is fast, positive, accurate, dependable.

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SUPER-TROL tells at a glance the condition of all equipment. Gives fast indication of all automatic operations. Uses a single pair of wires or carrier current channel for any and all operations. Can operate simultaneously with telephone conversations.

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"But you can't buy that kind of a motor..."

F-14A

How many times
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say something like that about
motors, pumps, compressors or
what-have-you? And how many
times have you heard somebody
else say, "Oh yes you can!
I saw just what we need in
Blank Company's ad yesterday."
Advertising pages in
this magazine are packed
with *news* about your business.
They contain information
about products and services
designed to help *you*
do your job quicker,
better and cheaper.
To be well-informed
about the latest developments
in *your* business,
your industry...
and to stay well-informed...
read all the ads too.

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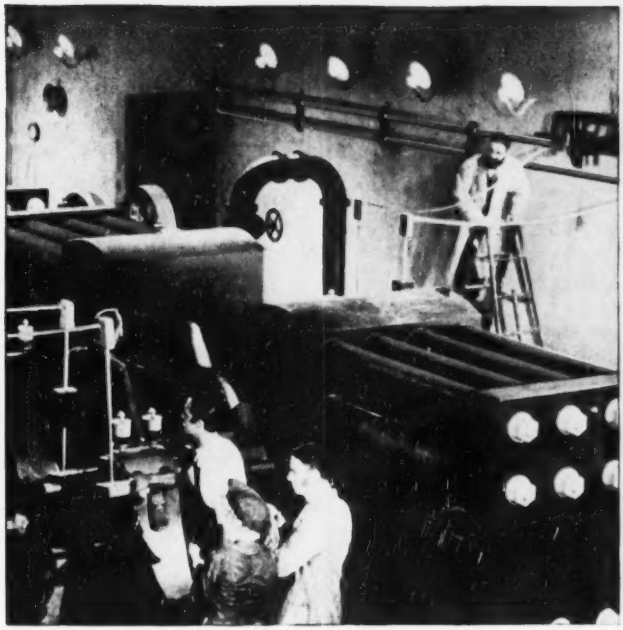

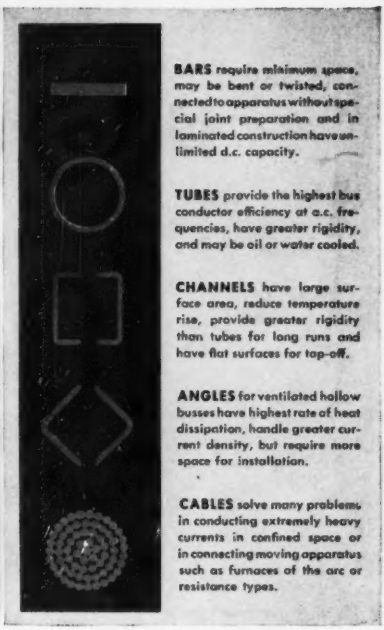

BARS require minimum space, may be bent or twisted, connected to apparatus without special joint preparation and in laminated construction have unlimited d.c. capacity.

TUBES provide the highest bus conductor efficiency at a.c. frequencies, have greater rigidity, and may be oil or water cooled.

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CABLES solve many problems in conducting extremely heavy currents in confined space or in connecting moving apparatus such as furnaces of the arc or resistance types.

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FROM FIRST.....TO LAST

COPPER is the Best Conductor

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Since that day, the original plain, light copper strips and rods, have been succeeded by continually improved bus conductors. In the early 90's the Coe Brass Company, another American Brass constituent, and the Ansonia Brass and Copper Company began cutting bus bars from rolled copper plates and then cold-drawing them to finished dimensions.

As electrical loads became heavier, and required more complex bus structures, the Coe Brass Company, which had been using extrusion presses to form intricate shapes of large cross-section, applied this equipment to the fabrication of heavier bus shapes, in the form of angles and channels.

With each succeeding advance in design of electrical generating and transmitting equipment, The American Brass Company has kept pace in creating and manufacturing new types of bus sections of copper, then and now the most satisfactory material for that purpose.

ANACONDA
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Anaconda

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Fourteen inches back of that screen runs a high tension bus. Let a man forget to trip the supply oil switch before opening that protecting door and he'd never forget again. But with this SAFEGUARD, he CAN'T forget.

To open the door equipped with a SUPERIOR type B-1496 Interlock he must have the key. And to release that key from its present location, he must open the line oil switch and lock it open. Then, and only then, can he get at the bus.

SUPERIOR Interlocks are built in dozens of types and designs to guard against the kind of human error or memory failure that spells F-A-T-A-L-I-T-Y. Send for our new catalog or ask us for specific suggestions on the form of Interlock best suited to meet your own current protection problem.

Authorized and Exclusive Service Representatives for the Bendix-Cory Interlock System

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READ THE ADS.

To help you . . .
Install, maintain and operate

ELECTRICAL EQUIPMENT

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AMERICAN ELECTRICIANS' HANDBOOK

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1734 pages, 1327 illus., over 400 tables
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Bigger and Better New 6th Edition— In Accordance with 1947 National Electrical Code

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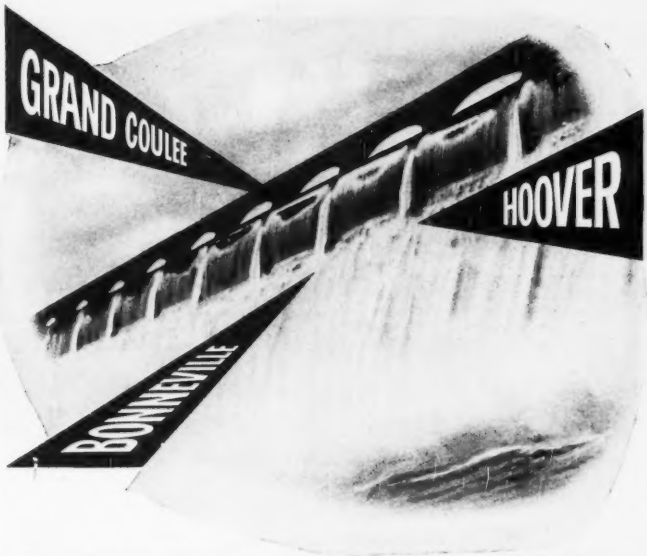

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C-O-TWO

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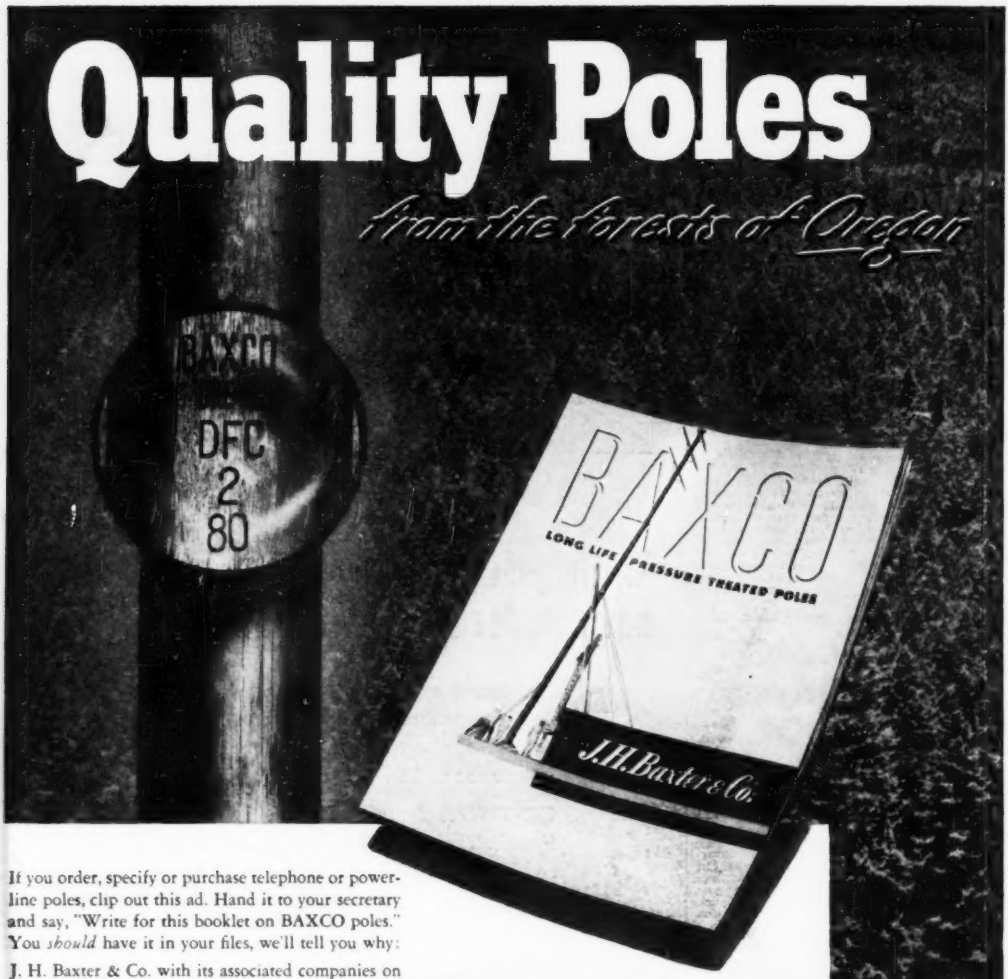
Sales and Service in the Principal Cities of United States and Canada
AFFILIATED WITH PYRENE MANUFACTURING COMPANY

Quality Poles

from the forests of Oregon



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J. H. Baxter & Co. with its associated companies on the Pacific Coast are one of the principal suppliers of poles in the west. As producers of BAXCO Long-Life Douglas Fir pressure-treated poles, we lay claim to be the producers of the very finest poles in the world. Just why these poles are better; why these poles are economical to buy; why these poles are available on prompt shipment is all told in the book.

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J.H.Baxter & Co.

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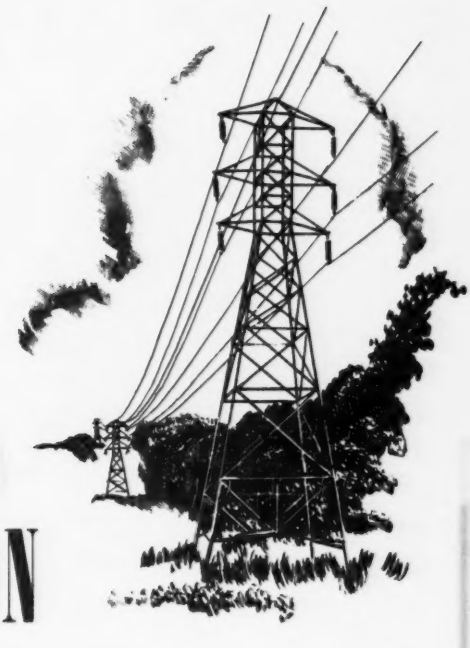
ASSOCIATED COMPANY: J. H. BAXTER & CO. OF OREGON

Producers of Quality Poles for Over 30 Years



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TRANSMISSION LINE DESIGN

TRANSMISSION OPERATION AND MAINTENANCE

POWER TRANSFORMERS

POWER CABLES, MEDIUM AND HIGH VOLTAGE

Lightning was the bugbear of transmission until one of the most concerted and aggressive technical attacks brought about today's virtual immunity of transmission lines, transformers, cables and related apparatus. Need for an answer has motivated the thinking and the activity for more than two decades. Once that solution was practically assured the emphasis reverted to the mechanical, insulation and operational problems of the cross-country circuits exposed to ice, wind, temperature changes, birds, salt-fog and other obstacles to service continuity. Concurrently the power transformer was undergoing dielectric, magnetic and structural advances aimed at larger ratings, less vulnerability and lengthened operation with minimized attention. Simultaneously demand for bettered performance of cables was coupled with need for higher voltage ratings and assurance that insulation voids would not form and lead to ionization and breakdown. The ensuing papers reaffirm the stages of progress.

PUSH OUT
AND FOLD

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Transmission Line Design

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Transmission Line Design

Field and laboratory research showed the way to lightning-proof line by substantiating wood insulation ground, wires, minimized tower-footing resistance, arresters, tubes, shields, counterpoises and coordinated insulation

TRANSMISSION SYSTEMS of 25 years ago did not have imposed on them today's heavy responsibility of providing continuous and uninterrupted flow of electric energy from the distant generating station to load centers and the ultimate consumers. Forward thinking engineers even then visualized the large electric power requirements for industrial expansion, improved living conditions in populated areas, and also for rural electrification. The small and isolated plants were inadequate to meet this challenge; and high voltage transmission as we recognize it today began assuming major importance.

Major problems involving lightning resistant lines, system stability, insulators, line hardware, relaying, corona, conductors, conductor vibration, and structures—both wood and steel—all confronted the transmission art; they had to be solved both practically and economically. It is the intent to present and briefly discuss here some of the high points of these problems.

Lightning on Transmission Lines

That lightning was one of the major obstacles to the successful operation of high voltage transmission lines of even moderate length was soon recognized. In fact, in the early days of some small electric systems, it is reported the electric systems were purposely shut down during electric storms to prevent failure of apparatus and damage to the line. Although this practice was abandoned by a quarter of a century ago, very little practical benefit to the transmission line had been accomplished to limit the destructive effects of lightning. This was because little or nothing was known about the mechanism of natural lightning and its effect on transmission systems. The idea was still held by some, 25 years ago, that lightning was a phenomenon of nature and little or nothing could be done to control it on electric power systems. But some engineers in the transmission field believed lightning could be controlled, and set out with enthusiasm and perseverance to prove it.

Instruments Devised

Measuring instruments for the study of lightning were developed of various types and in considerable volume. First there was the klydonograph in 1924, closely followed by the surge voltage recorder, the cathode ray oscillograph, the lightning stroke recorder, and later such instruments as the surge crest ammeter, the crater lamp oscillograph, the photographic current recorder, the voltage and current wave slope indicators, the fulchronograph, and others designed for field use.

The field investigations were first undertaken by a few of the larger utilities and manufacturers of electrical equipment on a cooperative basis. Other utilities joined in the work as the research progressed. Mention should also be made of valuable contributions made by the theorists who more than kept pace by means of their analytical studies and correlation of theory and field data. Thousands of records of lightning voltages and currents appearing on transmission lines were obtained, as a result of which a much clearer picture of the lightning phenomenon was obtained.

Lightning Generator

In addition to the field investigations initiated some 25 years ago, the lightning generator and cathode ray oscillograph were developed on a practical basis in the middle 20's to study the lightning or "impulse" strength of insulators and air, (which are the inherent insulation of a transmission line), as well as the similar strength of terminal equipment.

While the research did not disprove that lightning was "an act of God," it soon became evident that lightning could be controlled on electric transmission systems and done economically.

Among some of the important characteristics of nat-

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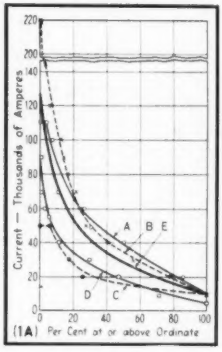

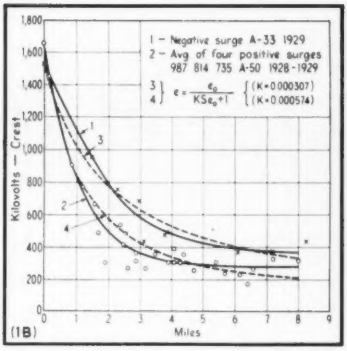

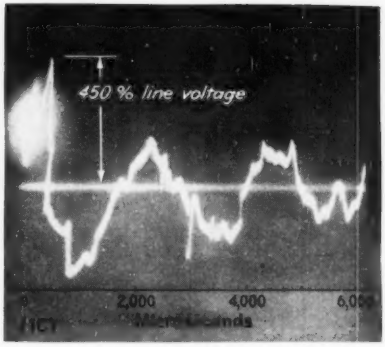

FIG 1A—MAGNITUDE of lightning current strokes determined from field measurements—A, by ground wire currents; B, by sum of adjacent tower currents; C, by tower-top lightning rods; D, single tower currents; E, average of A, B and C

FIG 1B—Attenuation of lightning voltage on a 132-kv transmission line measured by surge voltage recorders. Note the rapid attenuation of both positive and negative surges to half value in about two miles

FIG 1C—Switching surge voltage on 132-kv line measured as 450% of normal line to ground voltage with oscillograph

ural lightning on transmission lines, which were determined from the research are the following:

1. The lightning voltage on the line was limited to the flashover value of the line (insulators, or conductor spacing).

2. Lightning voltages as high as 4,500,000 v were measured; and as high as 15,000,000 v are believed possible, if not limited by line flashover.

3. The destructive voltages are largely local, and attentuate or decrease rapidly with distance.

4. Lightning currents in a stroke to a line reach the order of 150,000 to 200,000 amp as a maximum but only infrequently.

5. Lightning strokes are predominantly negative in polarity (about 85%), and are in general nonoscillatory. (Where oscillations occur, they are of negligible importance).

6. The duration of a single lightning stroke is relatively short (in the order of 100 microseconds or less, so far as protection against flashover or failure of insulation is concerned).

7. The lightning stroke is multiple in character in some cases (percentage-wise perhaps 25% or so being multiple discharges).

8. The lightning, or surge, strength of line insulation is quite different from its power or 60-cycle voltage strength. Present day thinking recognizes the volt-time characteristic of all insulation as being of most significance rather than the impulse ratio.

Standard Waves

The determination of insulation lightning strength was greatly aided and clarified by the introduction of standard impulse test waves, based on information obtained from the field studies of lightning. Our present day 1½ x 40 microsecond wave is an important by-product of field investigation.

9. The induced stroke theory, whereby nearly all lightning disturbances on transmission lines were thought to have originated by the release of a bound charge on the line conductors, was discarded for the direct stroke theory.

10. Direct lightning strokes to line conductors can be effectively prevented by properly placed ground, or shield wires located above them.

Some of the numerous steps taken in rendering transmission lines highly resistant to lightning are of interest.

Lightning-proofing Transmission Lines

Interruptions to service were experienced about 25 years ago to such a degree in lightning territory that the ability of the lines to supply reliable blocks of electric power to load centers was of great concern. One 73-mile line is reported as experiencing 88 cases of trouble from lightning in 1925 resulting in a large number of service interruptions, as well as damage to insulators, and burning of conductors and line hardware. At this time the value of ground wires was a controversial subject; in fact, they were being removed on some lines in the belief they were doing more harm than good. Relay operating times were slow, being in the order of seconds instead of cycles as at present; and breaker clearing times were likewise long resulting in a concentration of energy at the insulator string where the lightning flashover initiated.

Corrective Steps

The corrective steps taken in this case were several. First, grading or arcing shields were placed at the line end of the insulator string in an attempt to divert the arc flashover path to air instead of over the insulator surface. A ground wire was installed over the entire line, and relay times were shortened as much as possible with the existing relay systems then available. The number of insulators per string was increased, and the line clearance to tower was also increased. As a result of these changes, greatly improved lightning performance of the line was obtained.

The near lightning-proof line was not even visualized at that time, but the various suggested methods to

mitigate lightning troubles on the transmission system were proposed, and many were tried out.

Over-insulation

Over-insulation, such as adding some 20% additional insulators on 132-kv lines and up to 100% over-insulation on 66-kv lines, was tried. It was thought that the maximum lightning voltages on 132-kv lines might be only slightly higher than the generally used insulation, so that some 20% increase in insulation would greatly reduce the lightning flashover of the line. Doubling the insulation on 66-kv lines, it was thought, while not reducing lightning flashovers to a satisfactory limit, might prevent line interruption by reason of the longer power arc path over the insulators perhaps being self-extinguishing. Neither of these two theories worked out satisfactorily in practice.

Wood Insulation

Another form of over-insulation, however, did prove highly successful. This was the addition of wood. The lightning strength of poles and crossarms inherent in wood pole line construction was ingeniously utilized by substituting wood crossarm braces for the standard metal braces, insulating guy wires with wood, and offsetting the pole grounding wires to obtain an electrically balanced construction. A typical pole design using this construction is shown in Fig 3. This construction has found extensive use in the medium voltage lines from 22 kv up to even 110 kv.

Ground Wires

By theory and operating experience during the past 25 years, the ground wire properly located and suitably grounded has proved itself highly effective in rendering a high voltage transmission line practically lightning-proof. Tower footings in the range of 10 to 25 ohms, depending on the line voltage are generally acceptable, although it is often not practical to obtain these low resistances in some types of territory. At the present time adequate shielding is obtained with two ground wires, and often with only one.

Ground wires are often strung with less sag at mid-span to increase the lightning strength of the line.

Mechanical troubles from ground wires which existed 25 years ago are practically non-existent today, because they are supported and maintained with the same care as are the line conductors.

Tower Footing Resistances

To be highly effective the ground wire must be connected to earth by a low resistance (low tower footing resistance). Grounding in addition to the normal tower footings has been done by the use of ground rods and counterpoises. Ground rods as long as 150 ft or more have been used in some locations. Counterpoises, which take the form of conductors buried 18 in. or so under ground, or in some rocky locations on top of the ground, have been used in various configurations (Fig 4). The merits of the different types are still a matter of opinion, but are usually judged largely by their measured ohmic resistance.

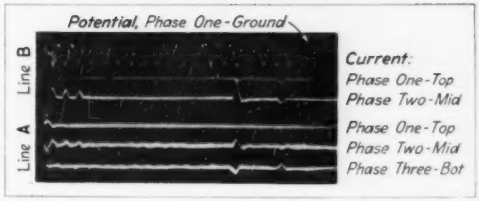

FIG 2—MULTIPLE CHARACTER of lightning stroke to 132-kv line shown by cathode ray oscillograph record

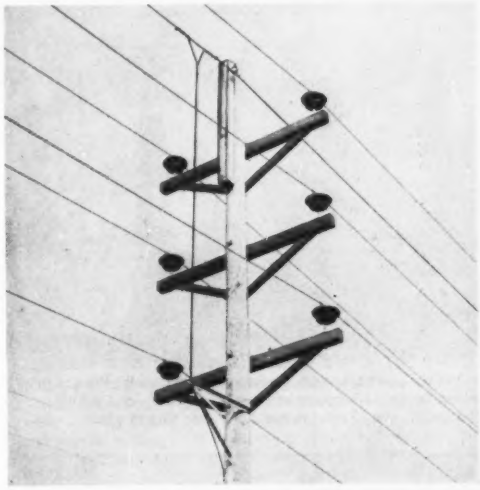

FIG 3—33-KV WOOD STRUCTURE showing use of wood crossarm braces, and pole top extension for ground wire to increase lightning strength of the line. Note the ground wire downlead offset to increase the lightning strength of the structure

Lightning Arresters

The use of conventional lightning arresters on line structures to make a line lightning-proof was tried in a very limited way in the early days without outstanding success. While theory indicates the scheme should be highly successful, economics prove it impractical. The cost of protecting a high voltage line in this way might well in some cases double the initial cost of the line.

Protector Tubes

Protector tubes have been applied to some extent on intermediate voltage transmission lines from 22 to 110 kv. In the voltage range above 110 kv their very limited service life presented a definite obstacle. In addition their operation did not correlate well with high-speed reclosing breakers. In the 33 to 110-kv voltage range, however, a number of successful applications have been reported. A typical protector tube application on a 132-kv insulator string is shown in Fig. 5A.

A particularly novel method of application has been adopted by one company on 33-kv class lines where one

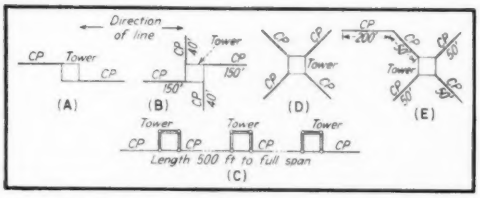

FIG 4—TYPES OF COUNTERPOISE used to reduce tower footing resistances in the control of lightning voltages on transmission lines . . . (A) Longitudinal counterpoises . . . (B) Star counterpoises . . . (C) Continuous counterpoise . . . (D) Crowfoot counterpoise . . . (E) Combination of (A) and (D)

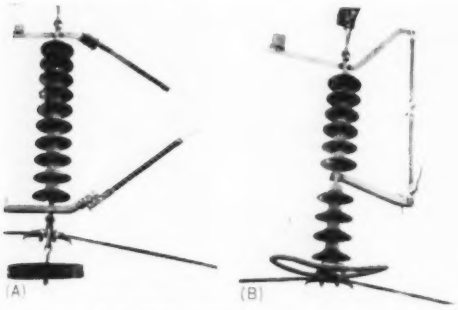

FIG 5—PROTECTOR TUBES mounted on 132-kv lines . . . (A) V-Type mounting with grading shield removed. Weight is to prevent uplift on insulator string at this particular location . . . (B) Parallel type of tube mounting—arcing ring in place

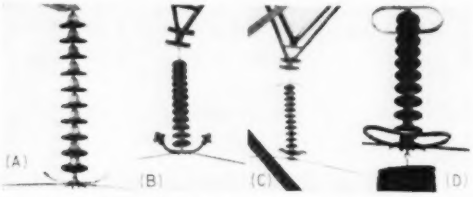

FIG 6—ARCING AND GRADING SHIELDS used in the past on insulator strings to prevent damage to insulators and conductors . . . (A) One of types first used . . . (B) Flux control type . . . (C) Ring and horn type . . . (D) Ring and ring type

protector tube per wood pole structure is used connected to the top conductor and spaced along the line several span lengths apart. The top conductor acts both as a line conductor and shield wire; the lightning being intercepted by the top conductor is diverted through the protector tube to the downlead on the pole. A considerable reduction in lightning outages has resulted from this type of line construction, with a great economic saving in the initial cost of protector tubes.

Arcing or Grading Shields

The arcing, or grading shields as sometimes called, were initially used to hold the power arc clear of the insulators in the string and to prevent conductor burning. The first arcing horns consisted of a single short horn attached to the conductor hardware. One form consisted of arcing horns with electrodes terminating in a shape simulating inverted spoons, it being claimed that the breakdown path approximated sphere gaps. Still another form consisted of a double horn electrode at the line end, the electrode being terminated in a small insulator which was spaced to effectively distribute the voltage stress on the line unit. Later designs assumed various forms; a common type was the oblong ring attached at the line end of the string, and a double horn, or ring at the ground end.

Most of these types, as well as some modifications, were successful to a considerable degree in minimizing damage to the insulators in the string and to the conductors. Some of the typical forms of construction used in the evolution of arcing rings are shown in Fig 6.

The necessity for arcing rings today has practically vanished because relay times and circuit breaker interrupting times have been so shortened as to limit the dissipation of energy at the point of fault.

Fused Grading Shields

Fused grading shields were also tried. These consisted essentially of the conventional grading shield with a fuse similar in many respects to the protector tube attached to one end of the shield and an air gap between the opposite end of the tube and the other shield. The purpose of the fuse was to interrupt the power flow and thus prevent a circuit outage. One serious objection to this device was the fact that after one operation it had to be renewed, and also the protection was lost temporarily until the line could be inspected and the fuse replaced.

Ground Fault Neutralizers

With medium voltage lines the Petersen coil (now called ground fault neutralizer) was used with a considerable degree of success to prevent lightning outages. This device consists of an inductance placed in the system neutral and tuned to the line capacitance. Some 100 of these coils are in use today on systems of 2.4 to 140 kv and provide a high degree of immunity from lightning troubles. They have some inherent objections: First, they are not effective under phase-to-phase fault condition; second, they may become badly out of tune if the system is even momentarily split during system disturbances, and they require the system neutral to be isolated, which in the higher voltage systems does not permit the use of reduced insulation which, in turn, has been economically applied on many high voltage systems today.

Ultra High Speed Reclosing

The ultra-high-speed reclosing circuit breaker in combination with fast carrier-current relaying has proved one of the most successful methods of lightning proofing transmission lines. It is based on permitting the lightning to flash to ground, quick deenergizing of the circuit, and reestablishing power flow after an interval of time only sufficiently to deionize the arc fault path. The whole operation of clearings the fault and reclosing according to present day practices is in

the order of 12 to 18 cycles, which has proved satisfactory in preventing customers' equipment from dropping out of step and power interruption of an objectionable character.

Experience Under Lightning

Much statistical data on the lightning performance of lines from 26 to 220 kv are recorded in the technical literature within the last quarter century. Analysis of these records gives definite proof of the value of the various devices and schemes used in actual service. For example, it is shown that one means of mitigating lightning outages is the use of two circuit lines instead of only one circuit. This, of course, can be justified only where normal power requirements demand two circuits. These records show great benefits from reducing line outages by the use of ground wires, low tower footing resistances, and adequate shielding.

Calculation of Lightning Performance

It is now possible to predetermine the lightning performance of lines with a considerable degree of accuracy, as shown in fairly recent technical literature. Thus from some 25 years ago when practically nothing was known about the behavior of lightning on transmission lines, we are today in a position where the problem has been reduced to one amenable to calculation with engineering accuracy.

MECHANICAL FEATURES

While the frontal attack on lightning on the transmission system was being energetically pressed, other features of the lines presented many problems requiring solution.

Insulators

The troublesome problems of porous porcelain which in the earlier days had plagued the industry in the high voltage field had been practically overcome by 1926. The technique of joining the porcelain to attachment hardware, to produce reliable insulators, was well on a way to a solution.

The longer spans and higher mechanical loading required by the longer high voltage lines, resulted in a demand for higher strength suspension insulators. The 9,000-pound (tensile strength) units of the early 20's were supplemented by the 15,000-lb unit, and later by 25,000-lb, and even by 35,000-lb units in special cases. Shock-resistant porcelain was developed by the use of special glazes, thus reducing insulator breakage in handling and in service.

The use of pin type insulators in the medium voltage field (33 to 66 kv) has gradually given ground to the extensive use of suspension units largely because of the greater reliability of the latter.

Another insulator problem encountered was "insulator contamination" due to atmospheric conditions. Salt spray, smoke, industrial dirt, cement dust, and chemical fumes produced conditions, usually local, which caused line flashover troubles. To overcome this, extra insulation, or special insulators having increased leakage distances have been used with varying degrees of success.

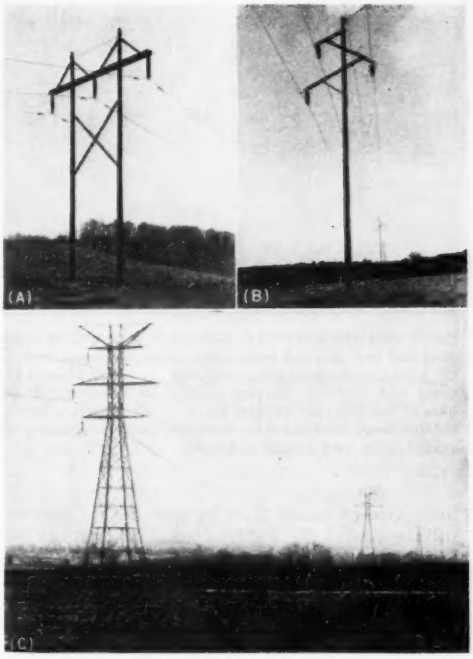

FIG 7—TYPICAL present day transmission towers . . . (A) Single-circuit wood construction with additional bracing between poles and the top to stiffen structure for long span construction and provide maximum of lightning insulation—132-kv line. Note conductor dampers on each side of suspension string . . . (B) Wishbone type of construction on 69-kv wood pole line utilizing wood crossarms for both lightning strength and for added mechanical strength . . . (C) Two-circuit steel tower with only one circuit strung. Note large offset between conductors and between conductors and ground wires, also small shielding angle furnished by the one ground wire already strung

In some locations periodic insulator washing, often with the line "hot" or energized, at voltages as high as 220 kv has proved a method of controlling the trouble, although not eliminating it.

The basis on which transmission lines are insulated today is to provide insulation to withstand, with a reasonable factor of safety, the dynamic and switching surge voltages expected, with due consideration to contaminated atmospheric conditions. To fully insulate against lightning by insulators only is not practical; therefore, additional insulation, in excess of the requirements, is usually determined by the expected improvement of lightning outage performance when used in addition to other lightning protective features worked into the line design.

Line Structures

Twenty-five years ago line structures had not been generally standardized to any degree. Steel was quite extensively used for lines operating as low as 22 and 33 kv, although wood was also used in many cases up to and including 110 kv. At railroad crossings steel struc-

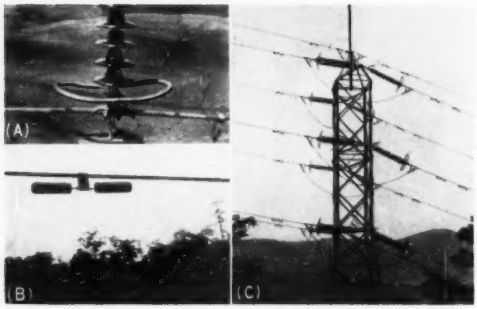

FIG 8—ARMOR ROD (A) in place on conductor. Note tapered wires and near spherical termination of the armor rod ends . . . (B) Vibration damper on line conductor . . . (C) Dead-end 132-kv tower with vibration dampers installed on conductor at both sides of the structure. At this tower are also shown a lightning rod and surge crest ammeter measuring links on lightning rod, ground wires, and ground conductors

tures were frequently used because the railroads were still skeptical of the ability of wood structures to stand up in service. This objection does not now exist because of the high reliability of wood construction proven by years of satisfactory service.

That wood in wood pole structures had lightning strength which might be effectively used was determined in the laboratory with the lightning generator and cathode ray oscillograph, and later proved in field service.

Wood Crossarms

In many cases steel crossarms were employed on wood poles thus reducing the lightning strength of the structure. The requirement for higher resistance to lightning resulted in the present extensive use of wood crossarm braces on medium voltage lines and occasionally on lines operating as high as 132 kv. One reason for the more extensive use of wood poles in the medium voltage lines is the development of wood pole impregnation by vacuum processes which has greatly increased the pole life.

High voltage towers and structures today, although not technically standardized, generally follow designs pretty much accepted and proved in service within the past 25 years, although variations are found. Some typical present day outline designs are shown in Fig 7.

Conductors and Ground Wires

Apart from the required current carrying ability of conductors, some of the important features required are discussed below.

The low strength of all-aluminum cable has been overcome by the use of a stranded steel core, thus still retaining to a large degree its advantage of lighter weight. Long span construction, with consequent saving in tower costs was a claimed advantage which was widely utilized.

The more severe burning of aluminum conductors under arc fault conditions was overcome by the use of armor rods which also contributed to some degree in minimizing conductor vibration troubles.

Destructive conductor vibration, which was found to exist under special conditions of wire tension and wind direction and velocity, was eliminated after intensive study and tests. This was done by the use of vibration dampers or weights attached to the conductor near the tower or structures. Typical armor rods and vibration dampers are shown in Fig 8.

In the highest voltage range the conductor outside diameter becomes important in controlling corona loss. Ingenious methods have been developed to provide the larger diameter required and still building into the cable only the required current capacity. With copper this has been done in two ways: First, by the HH cable which is essentially a tube with the side walls of interlocking copper ribbons or strips, the center being hollow; and second, by using a spiral I-beam core of short lay over which the conventional copper stranding is placed with reversed lay. With the aluminum cable, the steel core is retained, wrapped with a water repellent jute or fiber, and the customary aluminum stranding applied over all to give the required diameter.

Ground wires have developed from the accessory or nuisance stage of 25 years ago to conductors of the same importance as the current carrying wires. They are usually now made of ACSR, copper, Copperweld, or galvanized steel and are giving entirely satisfactory performance. The methods of attachment to structures have been altered to eliminate rigid connections which had produced vibration failures.

Conductor Joints

In joining or splicing conductors the twisted sleeve joint and clamped and threaded types are giving way rapidly to the compressed terminal joints where large currents are involved. Excess heating and burning of the older type joints as current loading increased made this change necessary. Within recent years entire existing lines have been completely changed to the compression type connections both at splices and cable terminals.

Line Hardware

The development of line hardware over the past 25 years has been mostly along the lines of refinements rather than major changes. Suspension clamps have been designed which not only support the weight of the conductor, but also grip it without deforming or damaging the outside surface. Proper "takeoff" angles of standard clamps have been worked into designs to meet practically all expected field conditions of terrain. The lip of the clamp has been shaped to prevent undue stress or damage to the conductor.

One major trend has been the design of lighter clamps and fittings by greatly improved malleable iron, and occasionally by the use of steel forgings.

Of recent interest is the use of non-magnetic suspension clamps for high current carrying conductors, thus eliminating the magnetic circuit around the conductor. The advantages are a reduction of energy loss in the line, and a lower temperature rise at the clamp.

Line Loading

There are two important features of line loading: one is the mechanical loading, and the other the kw or current loading. Both are to a degree interrelated. The larger the kw the line has to carry, the larger the line conductor: the larger the conductor, the heavier the load to be carried by the conductor weight, and by ice and wind, and the heavier the load that must be carried by the line towers. The stresses on structures under any condition of loading are well understood, and factors of safety have been worked out and used in the field with satisfactory results. With this background, the entire country has been divided on the basis of long term weather records into areas of light, medium, and heavy mechanical loading, and standards of acceptable loading in these areas agreed upon. This has aided in the building of economic lines throughout the entire country.

The heavier electrical loading of lines, or more broadly, the requirement of transferring larger amounts of electrical energy with economy and reliability has resulted in placing added burdens on other parts of the electric system of which the transmission lines are the vital links. Among these are:

1. Higher interrupting capacities of circuit breakers (now pointing to 10,000,000 kva).
2. System stability at time of faults (now, but not 25 years ago, determinable by the calculating or load study board).
3. High speed clearing of line faults (required for system stability, and for minimizing mechanical damage to the line).
4. Continuity of service (now attainable to a high degree by ultra-high-speed reclosing breakers).
5. Single phase switching on line faults to prevent power interruption and system instability.
6. Use of transmission lines for telephone, telemetering, carrier current relaying, and supervisory control.
7. Use of synchronous condensers to insure or improve system stability.

Sleet Melting

Another troublesome factor of similar nature is the formation of ice on conductors. Unloading sometimes occurs unequally on the conductors resulting in short circuits which persist until adjacent conductors are unloaded equally. Prevention of trouble is accomplished in two ways: First, care in the spacing of the conductors in the line design; and second, by melting the ice after it starts to form, and before it has built up to any appreciable thickness. Some systems in the sleet areas are equipped with carrier current sleet detection which gives advance notice of the formation of ice. The affected lines can then be heated by excess current by load transfer, by special switching arrangements to lower voltage circuits, or, with long lines, by short-circuiting at the distant end.

Miscellaneous Features

Even though a transmission system is planned, designed, and constructed with the most painstaking care, there are problems which arise after the line goes into operation which could not have been foreseen. Several such problems have arisen in the transmission field within the past 25 years.

One relates to "dancing conductors," a condition which occurs during a moderate wind accompanied by sleet on the conductors. The "dancing" or whipping of the conductors results in successive contacts between conductors, and consequent line outages which often persist for several hours. Suitable spacing of all conductors to minimize the possibility of line short-circuit is one solution. Fortunately, the required atmospheric and line conditions do not often occur simultaneously and then only in local areas.

The importance of line maintenance was early recognized, as the requirements of continuous service on the system became increasingly great. As a result, methods and tools for carrying on the necessary maintenance such as replacing insulators, adding armor rods, installing vibration dampers, and even replacing conductors without deenergizing the circuit were developed and used. "Hot line" maintenance is now routine procedure in practically all high voltage lines.

Transmission Lines of the Future

The transmission systems of the present time are the result of the continued and steady growth in the use of electric power to meet the varied demands in quantity and reliability. From the small household user of 1 kw of demand, to the industrial customer with several thousands of kilowatts of load, and even to the power companies with demands for block transmission in the hundreds of thousands of kilowatts, our present transmission systems have met all requirements without the slightest tendency to burst at the seams. This has been accomplished through the vision, fore-sightedness, and forward planning for the foreseeable future. Technical developments and ingenuity have kept pace with the increased demand for electric power. The question may well be asked, "What major changes can be expected in the transmission systems of the future?"

Higher Voltages

To provide block transmission from locations of low cost electric power to load centers will most likely require in some cases higher transmission voltages than the present generally used 220-kv lines. It seems reasonable to expect that higher voltage lines, networks, or interconnections will in the not too distant future be superimposed in some instances on systems and parts of the country where lines in the order of 132 kv have in the past carried the block load to the load centers. Certain it is, that many high voltage lines of the past are taking on the role of distribution lines by reason of the frequent tapping of such lines to supply substantial customer load along the route which they traverse.

Tests are now in progress in the field to study some of the technical features and limitations of transmission lines from 265 to 500 kv. Corona and other factors are being investigated so that when higher voltage lines are built, the design will be technically and economically sound, whatever the final voltage selected may be.

Transmission Operation and Maintenance

Live-line maintenance the rule. Insulators and connectors improved Corrosion checked. Dampers minimize vibration. Patrol by light planes and helicopters. Brush cleared. Two-way radio beneficial

MAINTENANCE OF TRANSMISSION LINES during the past twenty-five years has become a very complex problem.

With the lines loaded to capacity to accommodate increased demands for power, it becomes prohibitive to obtain extended line outage for repair due to vibration, metal fatigue, poor or defective insulation, inadequate structure design, etc. There are further problems caused by weather and changing conditions that require making practically all repairs with the lines energized.

There was a time when linemen were forbidden even to climb a steel tower or structure supporting energized 150-kv lines. Today, however, it is an accepted practice to perform any and all maintenance and repair on towers, conductors, insulators, ground wire, etc on energized 220-kv lines.

Increase of voltage from 150 kv to 220 kv, rather than construct additional expensive transmission lines to carry the added power, was a major project. It not only involved: (1) Adding insulators, but also (2) the raising of approximately 80% of the towers to provide adequate ground clearance for the higher voltage, (3) reworking the conductor terminals, and (4) installing tie-down insulators to stabilize conductor movement at towers where ground clearances were reduced by the longer strings of insulators.

Structures Raised and Moved

Steel towers have been raised up to 15 ft by use of steel lattice poles equipped with three-ton hand winches placed at each corner. Extensions have been placed beneath the raised towers, and hoisting equipment removed for raising the next tower, and so on.

In the case of bridge structures having two or three tower bases, the methods adopted were similar except that the structures were raised with screw jacks and cribbed up as the tower was raised to its final height.

Several tower relocations have been accomplished by placing the conductors in sheaves at suspension points and then moving the tower in line to its new location, up to 150 ft from its former base.

Connection Troubles

Added electrical loads caused failure of the electrical connections (jumper loop clamps) throughout an entire line. This was caused by three things—corrosion, lack of sufficient conducting area and the clamp not retaining a solid connection on wire. It was necessary to replace all jumper loop clamps with a larger clamp; each connection was treated with vaseline.

New compression hardware was adopted to elminate the troubles on the deadend clamps and also on the electrical connections.

Insulator Replacement

Insulation subsequently became a serious problem. The insulators originally installed were going "dead". That is, they were electrically "dead", becoming conductors instead of insulators. This condition arose from three influences on the insulators: (1) Line tensions (nominal 4500-lb), (2) thermal changes due to temperatures, and (3) vibration of conductors had a progressively bad effect on the insulators. Our transmission men worked with insulator manufacturers, and new insulator designs were perfected for major transmission line use but it was necessary to replace 160,000 insulators on our lines even so.

The art of insulator replacement has improved greatly over the old methods which required much physical exertion as well as line outages to perform the work on de-energized lines. Now the replacements are made with the line energized. A combination of insulated breakers, chain hoists, and insulated rope

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is employed in changing or replacing damaged or broken and defective insulators. Replacement of obsolete and standard insulators with fog-type units is easily accomplished, and this method is also applicable to suspension or dead-end assemblies as well as for the installation or removal of tie-down assemblies.

Insulator Testing

Prior to 1933, insulators on transmission lines were tested with a de-energized line insulator tester consisting of a Megger operated by a man on the ground, a stick handle with two prongs operated by a man on the structure, an insulated, twisted flexible copper cord connecting the two. It was necessary to de-energize and ground the circuit.

Some of the hazards of this type of testing were—when on a structure supporting more than one energized circuit, and where only the one could be de-energized, there was always a hazard of the cord, or the man on the pole testing, contacting an energized line.

Taking the cord through the levels of energized circuits at lower levels required having an extra man near those levels or securing the cord close to the pole at each level. The lowering of the handle and cord was as much of a hazard as taking it up.

In 1933, an energized line insulator tester consisting of two prongs and a small capacitance measuring meter mounted on an insulated, jointed stick was introduced. This type of tester eliminated the hazard of raising and lowering the equipment and the chance of testing the wrong line as all lines are treated as energized. All insulators on each structure supporting more than one circuit and all single circuit lines in the same area are tested at the same time. This eliminates all line outages, and the time formerly spent in returning to and reclimbing structures.

Cleaning and Guarding

Cleaning insulators during the 1920's by the steel wool and cloth method required line outages extending to several thousand hours.

The insulator washing method of today permits the cleaning of all the insulators on poles and towers with the lines energized.

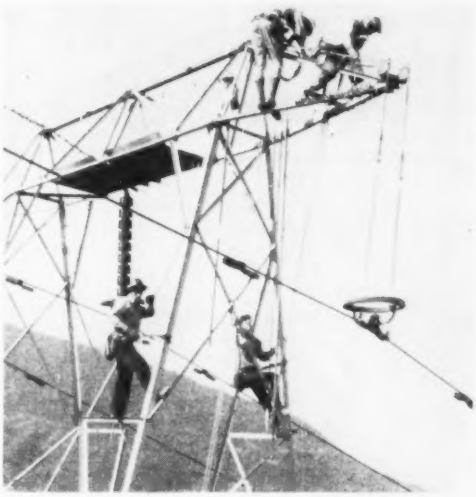
Insulator washing equipment employs high pressure pump, with 3/16 in. nozzle under a pressure of 800 psi.

With the higher voltage, serious flashovers or outages developed. Birds were found to be the major cause, especially ones roosting on the crossarms directly above the conductors. Experimentation produced a bird guard and bird pan which has eliminated 90% of the trouble.

Corroded Splices

Corrosion was our next big obstacle to overcome. Trouble developed in the conductor splices with the steel core rusting in two and allowing the aluminum conductor strands to part and fall. A conductor splice is, in fact, two splices. One splice holds the steel core, and a second splice around the first holds the aluminum strands and completes the electrical path.

TOWERS MOVED IN LINE after placing conductors in sheaves at suspension points



INSULATORS REPLACED on energized line

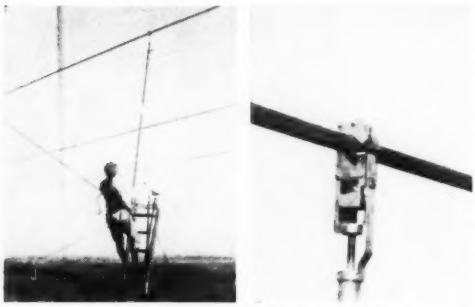
After about fourteen years service the aluminum-sleeve splice was allowing water to gather inside, which caused the steel to rust out, dropping the conductors.

A method of correction was worked out to do the work without taking the lines down. To do this, our men actually rode the de-energized conductors, drilled holes in the aluminum splice, drained water from the splice, flushed the splice out with red lead, forced a mass of celite and linseed oil inside the sleeve, tapped the aluminum to receive a screw plug and resealed the splice. Periodic examinations indicate that the splices are as good today as they were 20 years ago when they were treated.

Damaged Conductors

Broken strands on conductors are permanently repaired now by the application of an interlocking aluminum repair band which is placed on the energized

MACHINE for washing fog-encrusted insulators



STRAND-DAMAGED CONDUCTORS repaired from atop extension ladder. Close-up of tool at right

conductor by the use on an ingenious tool on the end of an insulated stick. This band has been successfully installed: (1) From towers, (2) atop a sixty-foot extension ladder, and (3) from boatswain's chairs hoisted by ropes attached to the overhead ground wire.

Vibration Dampers Effective

When our high voltage ACSR lines had been in operation only 12 years, we were faced with one of our most serious problems. Vibration was literally tearing our conductors apart. The aluminum strands of the conductors were found to be breaking at all suspension points. As high as 37 out of 54 strands were found broken. With over 500 miles of this type of line in operation and a new line under construction we were faced with a problem that meant terrific expense in replacing and repairing conductors.

A vibration damper (a line attachment that absorbs and eliminates vibration from line conductors without the usual effects of flexing the conductor to the point of fatigue failure) was developed by George Stockbridge (a former Edison Transmission Superintendent). It effectively reduced the vibration on the lines and extended the life of the conductors. The Stockbridge damper is now used throughout the world wherever transmission lines are in service. After this development was perfected, dampers were installed on all our ACSR conductors and ground wires throughout our system. This development alone has had far reaching effect on transmission line design, permitting us to use conductors of a higher strength value, pulled to higher tensions, so that now we use four towers per mile with very good results where formerly we were using eight towers per mile and were having very serious difficulty.

Armor Rod

While the damper has greatly reduced the vibration, over a period of years we found, however, that the strands were breaking under the suspension clamps and it became necessary to install armor rods.

By using insulated breakers, rope, and sticks, it is practical to lift the conductor, remove all insulators, suspension clamps, dampers, and suspension hardware from the line. The conductor is cleaned with a wire brush placed at the end of an insulated stick, then treated with vaseline, and armor rods are placed in position, and, with electric driven power through the insulated stick, they are served around the conductor. New suspension clamps are installed and, after replacing any defective hardware or insulators, they are reinstalled. Dampers are replaced on the conductor, and the inspection and repair is complete. The armorizing extends 3½ ft each way from the center and has made possible the elimination of the shield ring.

Pole Removal

The pulling of poles has been greatly facilitated by the use of two 15-ton hydraulic-operated pole jacks, which are placed on opposite sides of the pole to be pulled. Power is supplied to the jacks by a portable gasoline-operated hydraulic pump sitting on the truck and connected to the jacks by 20 ft length of hose. This method permits the use of a smaller crew for pulling old poles as the equipment can be easily operated by two men, whereas the manual method sometimes requires eight men to operate the jacks. The hydraulic jacks weigh approximately 80 lb each as compared to 100 lb for the standard pole jack exclusive of base chains, etc. The hydraulic system is more efficient than the old method and eliminates the linemen's objection to excavation around the pole, the handling of the heavier jacks, and the physical effort required to manually operate the jacks.

The progress of transportation has revolutionized the work of inspecting and prevention of transmission line failures. Automotive vehicles replaced the horse and wagon along about 1916, and what an event that was! With the powerhouse located 75 to 100 miles from

the consumer, and roads nothing but trails, the wagon patrolman spent days making the trip. Feed and water for the horse required more space on the wagon than the working tools. The automobile, however, could not entirely replace the wagons until roads could be built, and this required years for the conversion. On our system the last horse and wagon was not replaced until 1925.

Patrolling Lines

Another item of importance during the wagon days was the necessity of constructing cottages for the patrolmen. These were located along the transmission lines, in the mountainous areas, separated on an average of 20 miles. This was a necessity for quickly locating trouble. The automobile and improved roads gradually eliminated these dwellings and brought the families back to community living where their children could attend school. It required about 17 years of road construction and automotive improvement to entirely eliminate these outposts. The last one on our system was abandoned in 1933.

Between the years of 1925 and 1940 there was considerable improvement in the design and horsepower of the automobile and truck, and during this period the trend was toward reducing the number of patrol stations and consolidating the manpower into larger working units at central locations, whence good road and equipment could speed the repair crews to the trouble.

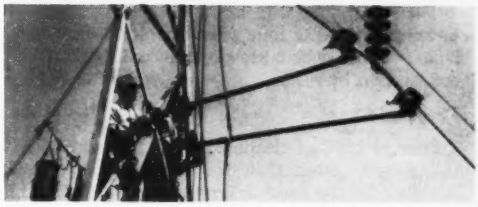
During this time air transportation was improving rapidly but very little thought was given to this new development for line inspection. The reason being that close vision was hazardous and the speed too great for efficient inspection. The helicopter was the answer to these problems.

Our first inspection by helicopter in 1947 covered over a thousand line miles (1550 circuit miles) and traversed terrain which varied from flat desert to wooded mountains, with elevations up to 6000 ft. On this patrol twelve locations of 220-kv ground fault, spotty rust conditions on ground wire, broken aluminum strands of the ACSR conductors, and several other items were detected, which had not been observed by the ground patrol.

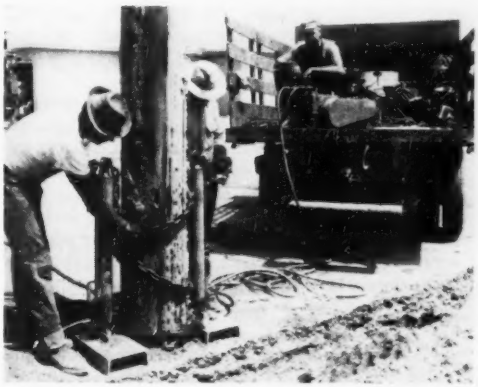
Helicopter Patrol

The helicopter can be flown 15 ft above and 50 ft to one side of the line, and it has the ability to stop, retrace a span, and land on almost any spot. An efficient inspection can be made at speeds varying from 35 to 50 miles per hour, in contrast to seven miles an hour by automobile, 15 miles per day with a horse and wagon, or 5 miles by patrolmen on snowshoes in the higher elevations.

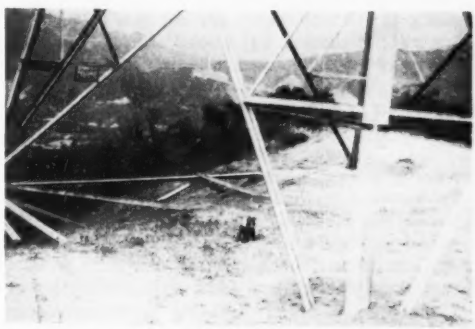
Recently helicopters were used very effectively to transport forty men and considerable material to an inaccessible 2,500 ft elevation in the Santa Ana Mountains where two transmission towers had been blown down during a severe wind and snow storm. The roads at the lower elevations were impassable and the helicopters saved the day.



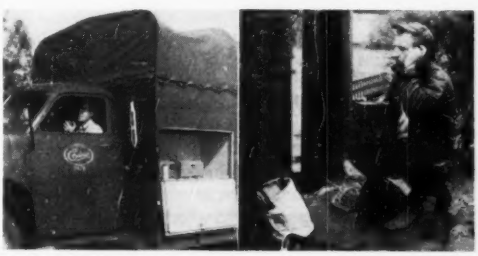
ARMOR ROD INSTALLATION in completion stages



THREE-MAN CREW removes pole by means of hydraulic jacks



TEST RESULTS from chemical weed-clearing



TWO WAY RADIO (left) offers numerous points of superiority over the hand telephone (right) of the mid-twenties

The regular patrol helicopter is equipped with two-way radio, and saves time when trouble occurs in mountainous terrain where mobile radio units cannot reach the location by road.

Fireguard Clearing

Prior to 1944 all clearing around transmission poles and towers, other than for experimental purposes, was done by the hand-clearing method or by machine where possible, such as bulldozers, graders and disk harrows. By using these methods it was necessary to start the clearing in the late spring and complete it by June 1st, or before the dry season started. To accomplish this it was necessary to build up many crews and engage a number of contractors to complete the work in a short period. Necessary employment of inexperienced men and contractors resulted in excessive costs and an increase in industrial accidents, mainly from poison oak in the mountainous areas.

In 1944 a program was started to sterilize the soil in the cleared areas with chemicals. This has proved very satisfactory as treatment can be made in the fall and winter months before the heavy rains which are necessary to soak the chemicals into the soil so as to reach the roots of the annual or perennial growth.

Non-toxic, Non-flammable

It was necessary to use a non-toxic and non-flammable chemical in all open areas. Most of the lines that were first treated in 1944 and 1945 have recently been retreated and we believe that no retreatment will be necessary for at least five years and possibly more. The cost of treatment for the first year is in excess of the cost for clearing, but when the treatment is effective for three or four years, it has proved more economical and eliminates the possibility of new growth from late spring or early summer rains after clearing has been made.

RCA (Rasorite Concentrates Anhydrous) borates are used for sterilizing the soil and are applied by the hand-sowing method or by a small hand sprayer. Should they be used in large amounts a machine spreader could be used to reduce the cost of application. It is found that one pound of borates per square yard is the amount required to effect a satisfactory kill.

Two-Way Radio Communication

The Southern California Edison Company transmission network consists of approximately 4,000 miles of transmission lines of voltage from 33 kv to 220 kv. The system is divided into four divisions with a total of 26 patrol and maintenance crews. These crews are responsible for the patrolling and maintenance of all transmission lines, and in addition to this, patrol and maintain approximately 5,000 miles of Company-owned communication lines.

Prior to 1948, all switching and emergency communications between the crews and the dispatchers or switching centers were handled over land lines; and on other than emergency or special work the crews were on a call-in basis of every two hours when communication lines were available. In some isolated locations no communication could be had with the crews between the time of leaving in the morning and returning in the evening.

In 1948, two-way radio units were installed in the trucks and cars used by the crews and supervisors. The equipment makes it possible for the crews to be in contact with their switching center or dispatcher at all times.

Crews Dispatched

Crews are notified of transmission line trouble within a few minutes after it occurs and, if necessary, additional help or material dispatched to the location without loss of time. Handy-talkies are used on major cases of trouble and in mountainous areas to furnish communication between structure locations to expedite repairs. Also the helicopter is equipped with two-way radio to patrol and report conditions of damaged lines in mountainous or remote areas which makes it possible to dispatch repair crews and materials to the location with a minimum loss of time. Mobile units may be used to communicate from car to car to expedite the work or relay messages to the switching center if necessary.

1. Two-way mobile radio has played an important part in reducing the outages to consumers in time of emergency.

2. Made it possible to have patrol and trouble crews to perform regular work and still be in contact with switching centers while performing this work rather than standing by on phone lines awaiting trouble calls.

3. Provided communication to a great number of areas where no communication was available heretofore, nor was it possible to supply communication other than by radio.

4. It has relieved an overloaded condition on a great number of communication circuits and made it unnecessary to construct new circuits to many locations for switching or substation maintenance purposes.

5. It has also contributed greatly in relieving the system dispatching problems in times of extreme emergencies such as large fires, storms, etc; this tends to reduce transmission outages.

Looking Ahead

The progress of the past twenty-five years has greatly increased the scope of the electrical art, but many problems remain to be solved by research engineers.

Progress will be made in the problem of conductor vibration, which poses many questions, especially in the higher frequencies of vibration where instruments to measure frequency and amplitude need to be developed before studies can be made.

To overcome corrosion, advancement will have to be made in producing non-corrosive metals. Also, improvements are needed in insulators to minimize the static discharge which, it is believed, contributes to corrosion of insulator hardware.

New designs and improved materials will be found which will increase the length of life of insulators beyond the point of mechanical and subsequent electrical failure.

Power Transformers

Efficiency, reliability enhanced by improved insulation and cores. Gains from coordination and impulse testing. Better cooling methods. Protected oil. Load-ratio control

In 1924 there was very little scientific knowledge upon which to design transformers to withstand lightning surges. Athough transformers had been built for operation at voltages as high as 220 kv, impulse failures in windings were all too common. The needs of the time focused attention on the problems of making transformers more reliable, efficient and economical.

Improved Insulation

Introduction of the cathode ray oscillograph in 1924, which made it possible to study lightning phenomena and to analyze the impulse voltage stresses existing in transformer windings, led to a fundamental advancement in transformer design. In this same period electrical manufacturers and users undertook extensive field investigations of lightning. There also came the development of high voltage surge generators capable of simulating the effect of lightning, thereby making possible laboratory studies which in a few hours could give data equivalent to years of field experience.

Some startling facts were learned about transformer insulation. For example, it was found that when the conventional high voltage winding of that time was subjected to lightning impulses, high initial concentrations of voltage might exist in the line ends of the winding, following which corresponding high internal voltage oscillations could occur. This showed that stresses much greater than previously estimated were occurring contrary to natural assumption, merely providing additional turn insulation was not adequate. Further, it was found that insulating barriers were weak in creepage to impulse voltages as compared to 60-cycle voltages. On the other hand, these barriers were found to have high impulse puncture strength.

Shielded Windings

Study of these problems led to the development of shielded windings in order to obtain a more uniform voltage distribution (Fig 1) and to minimize the effect of voltage oscillations. Insofar as possible, designs were altered to minimize creepage surfaces and to substitute for them insulation structures so arranged that failure must occur by puncture of solid material.

The studies also showed that under certain conditions, corona contributed to a progressive deterioration of the insulation. Once recognized, stress concentrations were reduced by smoothing joints, and applying the insulation in a manner that further reduced the voltage stresses. By more scientific application of insulation, not only was it possible to realize reduction in transformer sizes, but the performance record exceeded the most optimistic expectations of the engineers. More than one manufacturer can proudly assert that since about 1930 and the introduction of impulse-tested transformers, there have been no failures attributable to lightning or other line voltage surges.

Insulation Co-ordination

This record would not have been possible without the use of lightning arresters and other protective means on transmission lines. An early practice of providing lightning protection for the power transformer winding was to design the bushings so that they would flash over at a level below that of the interior insulation structure. Later, this practice was superseded by using co-ordinated rod gaps near the terminals of the transformer. More thorough testing of insulation and rod gap breakdown characteristics disclosed that unless the gaps were set comparatively close, they did not protect a transformer against a direct lightning stroke. With such closer spacing, the insulation level was reduced below that deemed adequate to prevent undesired flashovers from switching surges or recurrent arcs. In the light of this further knowledge, a major revision was made in the practice of co-ordination of insulation and the protection of transformers to withstand lightning. At this

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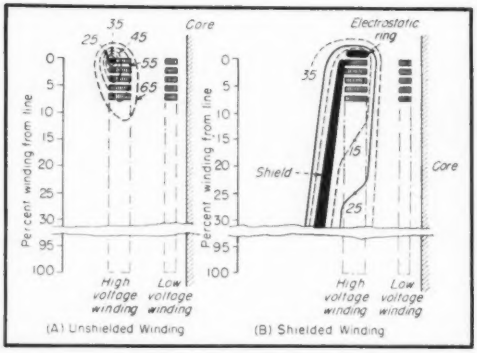

FIG 1—ELECTROSTATIC voltage distribution in transformers. Comparison of initial impulse voltage distribution in unshielded and shielded windings. Contours are percent of impulse voltage from line end to opposite end. With unshielded winding 25% of voltage stress appears across 3% of winding whereas with shielded winding the stress is approximately evenly distributed

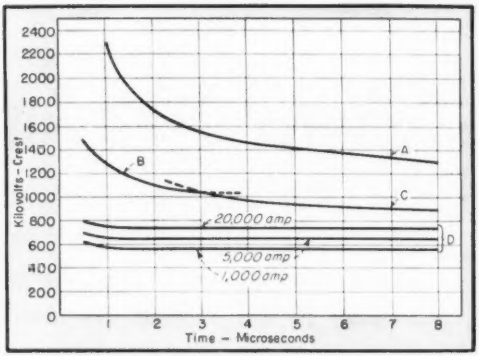

FIG 2—VOLT-TIME CURVES. (A) Flashover of 14-disk insulator string on 230-kv line. (B) Withstand impulse level of 230-kv transformer insulated for 196 kv. (C) Withstand impulse level of 196-kv transformer bushing. (D) Performance of 196-kv (maximum) lightning arrester (230-kv grounded neutral lightning arrester)

point, the modern lightning arrester became recognized as the base for establishing the protective level for transformers (Fig 2) It provided protection against steep waves arising from near-by lightning strokes, a protection which gaps could not provide.

As the protective level of the arrester is dependent on the maximum line-to-ground voltage of the transmission system under abnormal conditions, better protection can be provided for transformers operating on neutral grounded systems than on isolated systems. As a result, the trend is toward the use of transformers with lower insulation levels for grounded neutral systems where lightning arresters are properly applied.

Impulse Testing

The impulse testing of power transformers has been applied as a "proof-test" of transformer design. As such, it has contributed largely to the reliability of the transformers in service. From fundamental insulation studies related to stresses existing in transformer windings under various impulse conditions described above, sound basic design principles have resulted by which the insulation strength to be expected in the transformer can be accurately predicted under both standard impulse conditions and front-of-wave tests.

Experience has shown that the impulse test is a reliable method of controlling the final quality of transformer insulation. Although impulse testing of every transformer would give a final check on the proper processing and assembly of the unit, such a procedure does not appear justifiable as a standard test for all power transformers to supplant the more easily applied low frequency AIEE dielectric tests which were originally intended for this purpose.

Magnetic Materials

Fifty years ago, a transformer of 90% efficiency was considered to be of high standard. Now efficiencies above 99.5% can be obtained. The influence of transformer core material on operating efficiencies has long been recognized. More than a quarter of a century ago, non-ageing silicon core steel had been introduced. These hot-rolled steels have been continuously improved in quality largely by employing electrically-heated annealing furnaces and controlled atmospheres during annealing. Transformers can thus work at higher inductions for a given loss. Operating at higher inductions, the core section could be reduced in area, requiring less steel for the core. With the smaller core section, shorter copper turns were required, permitting a corresponding reduction in the amount of copper. Finally, smaller frames and tanks were required, thus reducing the overall size and cost of the transformers.

In 1931, the end of this long and valuable trend of improvement in ordinary silicon steel was foreseen. Research activities were then directed toward the development of a new type of silicon steel in which permeability and core loss were simultaneously improved so that the steel could be worked at still higher densities without increasing the exciting current.

Magnetic Orientation

This work resulted in the development of grain orientated cold-rolled silicon steel alloys. Structure is such that the individual magnetic crystals line up (orient) with their cube edges parallel to each other and parallel to the direction of rolling in contrast to the random pattern which is characteristic of ordinary silicon steel. The knee of the magnetization curve is lifted to a higher flux density.

In order to utilize the new highly directional steel most efficiently, modifications were made in the core design. In some cases, these changes involve radically different methods of building the core to eliminate undesirable corner effects and led to still further reductions in sizes and losses. Within the next few years it is expected that this steel will be used in practically

all power transformer core designs.

In this last quarter century, another step of great importance has been the better understanding of the cooling of the transformer parts. By 1924 most of the dry type air blast transformers had been replaced by oil-filled units.

Heat generated in the windings flows through the conductor insulation to the oil and, by convection, from the oil to the cooling system—either self-cooled radiators or water cooling tubes. In the self-cooled transformers, thermosiphon action causes the oil to flow through the radiators, and the heat is carried off by the surrounding air. Adhering to the external surface of the metal radiators is a film of air that retards the flow of heat. About 1924, a novel design was introduced that directed jets of air against the radiators for the purpose of scouring off this air film by turbulent action and, thereby, increasing the rate of heat transfer. Later, these jets were replaced by fans.

Water-cooled transformers, quite extensively applied in the late 1920's, have gradually lost favor because of the inherent disadvantages of requiring a location near a good low-cost water supply and the always-present danger of water leaking into the oil.

Pumped Circulation

Around 1937, steps were taken which radically raised the cooling efficiency of power transformers. Flow of oil was increased by pumped circulation, attention was given to directing it in specific paths through the windings, and then cooling it in external oil-to-air or oil-to-water heat exchangers, sometimes supplemented with ordinary radiators with or without fans. These improvements (Fig 3) resulted in a considerably smaller transformer and a great saving in material. With this new type of cooling, transformers with very high kva ratings can now be shipped completely assembled.

Transformer Oils

As transformer cooling methods were improved tendency was for the operating oil temperature to be raised. Oils that performed adequately at lower temperature suffered accelerated ageing at the higher temperatures. It was found that the highly refined insulating oils commonly used twenty-five years ago tended to form acids more readily than oils that had been less severely refined. On the other hand, the latter group were more likely to form sludge. By selecting the most favorable source of crude oils and carefully controlling the refining, a reasonable compromise was obtained. Further investigation of this problem has indicated that oxygen and moisture are the principal causes of oil deterioration.

Oil Protection

For this reason, the free-breathing type of transformer had been largely superseded by conservator transformers as early as twenty-five years ago. The conservator transformer breathes through a small auxiliary expansion tank of cold oil, thus reducing the absorption of oxygen and moisture to a negligible value

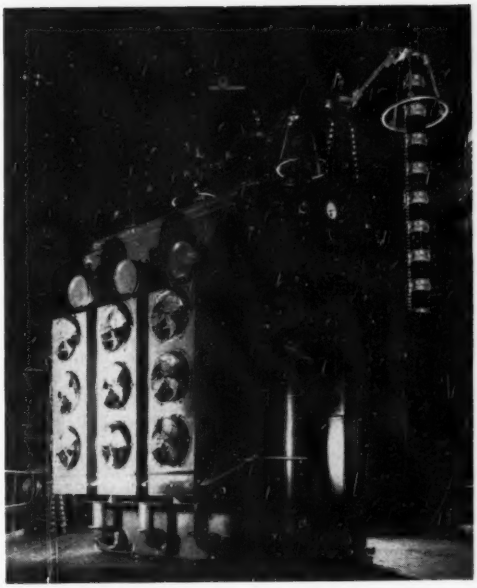

FIG 3—TRANSFORMER arranged for forced-air cooling

and minimizing the formation of sludge in the oil.

In the past twenty-five years, three additional alternative methods of oil preservation have been developed: Completely sealed—a space filled with nitrogen is provided above the oil; Gas seal—a cushion of nitrogen gas under regulated pressure is maintained in the gas space above the oil; Gas oil seal—the pressure in the gas space above the oil is maintained by a head of oil in an auxiliary tank (Fig. 4).

During the last few years, some consideration has been directed toward the use of inhibitors and continuously operating oil filters. Greatest interest, however, has been in their proposed application to the older free-breathing types of transformers. It is difficult to justify the extra cost of their use on modern transformers as experience indicates that any of the four present methods of oil preservation maintain the oil in serviceable condition for many years.

Improved Tank Construction

The benefits of improvements in insulation and its use, more efficient core materials, and better methods of cooling have permitted a great reduction in the physical size of a transformer for a given kva rating.

In some types of transformers a further improvement in the handling has arisen from using the tank as a dome over the core and coils thus saving time, equipment, and headroom for untanking the core and coils.

The fact that in some types of transformers the core material encloses the windings, has made possible another major development in power transformer construction—namely, the close fitting of the tank to the inside assembly, thus utilizing the transformer core and tank walls to complement each other mechanically.

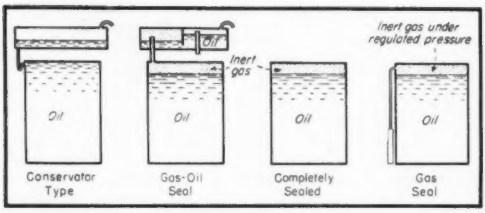

FIG 4—METHODS of oil preservation

With modern tank construction it is now possible to fill transformers with oil under vacuum, both in the factory and in the field, thereby eliminating the possibilities of trapped air bubbles which are unfavorable from the corona-forming standpoint.

Another mechanical improvement worthy of mention is the substitution of brazed for soldered or bolted coil connections.

Load Ratio Control

Twenty-five years ago, the rapidly increasing number of interconnections between power systems brought forward the problems of control of load flow, voltage, and the interchange of wattless kva. This need has been met by incorporating in transformers on-load tap changers or load ratio control equipment. By 1934 such transformers, had become firmly established. Since then separate oil circuit breakers for interrupting tap circuits have been superseded by built-in, oil immersed contactors; solenoid operation of switches has given way to an all-mechanical, motor-driven system; large voltage steps between taps, common in early designs, have been replaced by smaller steps; phase angle control has been applied to many system interconnections; completely automatic operation for controlling voltage is now available.

This period has seen the load-ratio control transformer become an accepted means for control, not only of voltage but also of the interchange of power or reactive kva in power systems. The trend during this period has been toward the use of completely automatic devices requiring a minimum of service, toward longer life of contacts to lengthen the time betwen replacements, toward higher accuracy of control elements, toward greater accessibility of parts, and toward a unit equipment housing leading to much improved appearance.

Unit Substations

The unit substation idea has also grown since it was introduced in the 1930's. By utilizing a packaged unit containing both transformers and switchgear, industrial users can concentrate in many cases on overall plans rather than on the details required to coordinate individual parts of the equipment. Installation expenses, if not overall costs, are reduced, and safety and appearance are often improved by using the packaged unit substation.

Unit substations have also been put on wheels to make them mobile. This plan eliminates the necessity for keeping many spare transformers and also allows fast and flexible replacement of transformers that are shut down for repairs or maintenance.

Noise Design and Testing

A quarter of a century ago, transformer noise was accepted as a problem of comparatively minor importance. More recently quiet operation and the elimination of noise has become more and more important. Advancement has been made possible by the improvements in apparatus for noise measurements and the availability of portable noise analyzers.

To classify a transformer as "noisy" or "quiet" it is necessary to take into account, not only the sound energy produced within the unit, but also the extent to which this sound is audible at the transformer location. The causes of transformer noise, the factors that aggravate it, and the various remedies for it are known. In fact, if price is no consideration, it is possible to build a transformer with substantially lower sound levels than required by present industry standards. But the general solution to the problem cannot be given by fixed standards because installation conditions affecting the acceptable sound level vary over a wide range.

There should be two criteria of transformer sound. That of the manufacturer, as exemplified by the NEMA standards, is based only on the voltage and kva rating of the transformer, and merely lists the lowest sound level possible to attain in a transformer without unduly increasing its cost. The yardstick of the application engineer, to which little attention has thus far been paid, should deal with the external factors affecting the audibility of transformer noise, such as the location of the transformer, the general ambient sound level, the proximity to residential sections, or the presence of other structures that tend to reflect or amplify the sound initiated by the transformer.

Transformer noise is troublesome in relatively few cases, but none lend themselves to a general solution. Each is an economic problem of balancing the additional cost of a quiet transformer against the cost of providing a suitable enclosure or locating the transformer far enough away for the noise not to be objectionable.

Overload Operation

In the past twenty-five year period and particularly during the war years of critical shortages of power transformers, more attention has been directed toward loading transformers in accordance with their temperature and its duration. By taking advantage of low ambients, heating and cooling of transformers due to load cycles, possible low temperature rise at rating and other factors, transformers may be loaded above nameplate rating under various operating conditions. Guides for such loading of transformers have been prepared by the ASA Sectional Committee on Transformers. These Guides give suggested loading to retain normal life expectancy and also that loading which may result in moderate sacrifice of life expectancy.

General recognition of these increased capabilities of transformers has led to more efficient use of capacity.

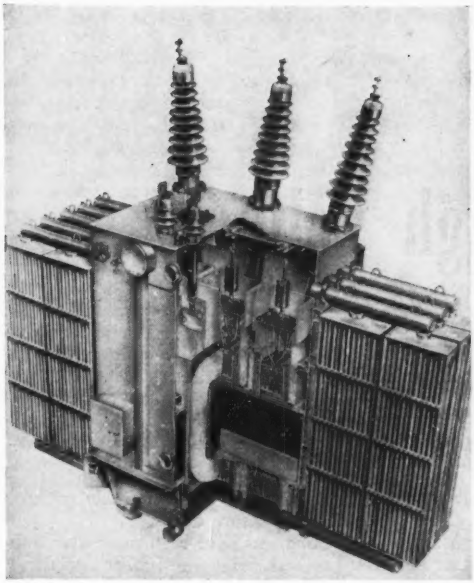

FIG 5—SHELL-TYPE polyphase transformer with form-fit tank

Cooling Medium Other Than Oil

The electrical industry had long felt the need for transformers to minimize fire and explosion hazards, to reduce the maintenance on such apparatus and to make it possible to install units indoors without the vaults required for oil-filled transformers.

Although mineral oil has had an excellent service record, it had always been recognized that there are a great many locations where it cannot be used for reasons of safety. By 1932 chemists had been able to synthesize a new insulating and cooling liquid which is now generally known as askarel. It has the desirable characteristics of mineral oil, but unlike oil it has extraordinary stability and will not burn, oxidize, sludge, or form explosive or inflammable gases. With this liquid, transformers can be located indoors, adjacent to the loads they serve, without expensive fireproof vaults. Askarel-filled transformers are now used in many locations where safety or cost of fire protection are controlling items.

Another important new development was the large dry-type air-cooled transformer for indoor applications. This transformer was originally developed for central station use, but found widespread application in industrial plants, office buildings, mines, chemical plants, and many other indoor locations. These transformers, like the askarel type, have made possible the installation of power supply and complete substations indoors at the center of the load, resulting in a more economical system of power distribution.

Inorganic Insulation

In 1936 a new type of air-cooled transformer for distribution voltages was developed to meet this need. This transformer was different from the old air-blast transformer in that its insulation was principally air, porcelain, glass, and other materials containing the minimum of combustible substances. It met enthusiastic acceptance because it filled an important need in the industry.

Dry-type power transformers are lighter than corresponding liquid-filled transformers. Core and coils are enclosed in light-weight but strong sheet steel cases with grilled openings at the top and bottom to provide an inlet and outlet for circulating cooling air through the transformer. The transformer with the attendant switches and circuit breakers may be installed indoors in substation buildings or in factories on the floor, suspended between columns or in the roof trusses.

In the past twenty-five years, the voltage and kva ratings of modern transformers have been pushed far beyond previous limits, and the physical size for a given rating has been considerably reduced. Availabilities in 1924 and 1949 as to voltage and kva size which could be shipped are as follows:

	1924	*Readiness to Build in 1949*
1. Maximum Kva per unit	25,000 kva	Above 175,000 Kva
2. System Voltage Kv	220.	Above 360 Kv (single-phase)
3. Maximum Kva shipped:		
a) Completely assembled	2500.	Above 75,000
b) With bushings and coolers removed	15,000.	Above 175,000

At the beginning of this 25 year period, reactance and temperature were the main considerations, and high efficiencies were not felt to be economically practical. Today progress in the art has permitted power transformer efficiencies above even 99.5%.

Through the use of such items as oil preservation, shielding, improved insulation design, and co-ordinated lightning arresters, the reliability of present-day transformers has been vastly improved. Users' confidence in this new reliability can be seen in the trend toward a single, three-phase unit rather than four single-phase units. Finally, the modern transformer has brought far-reaching economies to users. The price per kva of transformers has had an overall downward trend.

Looking Ahead

Problems to be solved range from a better understanding of the more intricate inside functionings of power transformers to their most economic application in relation to system operation. As examples, there is a need for greater mobility of power transformer units that will enable a reduction in the number of units required for spare capacity all over a utility system. Also, it is logical to expect to see wider application of new core forms not yet used in this country to achieve lower weights per kva of capacity. Far from being a stagnant field, the scope of opportunities for engineers in the field of power transformer design, application, and operation offers a stimulating challenge. It is reasonable to expect that the art will advance every bit as much in the next twenty-five years as in the past twenty-five.

Power Cables, Medium and High Voltage

Progress recorded for paper insulation, void-antidotes, sheaths, conductor control of tracking and corona cutting, sheath protection, rubber, synthetics and varnished cambric. Advent of pipe-type cable in oil and gas patterns

POWER CABLES and accessories have become commercially available for any operating-voltage requirements to date, ie, up to 230 kv in single-conductor cable and up to 80 kv in three-conductor cable; and for still higher voltages designs are available. In contrast, in 1924, many underground lines had frequent service failures, and no commercial designs existed for use at the higher transmission voltages.

Improved reliability has made feasible reductions in size or number of lines to serve a given load. The increases in the allowable voltages (Fig 1) have made possible the metallic connection of overhead to underground lines and the use of high-capacity transmission lines within cities.

Unless otherwise indicated, the present article pertains to the United States.

Attack on Losses

The impregnated paper-insulated, lead-covered cable is the predominating type. Its maximum operating voltage had risen from 110 v in 1895 to 25 kv in 1900. No particular progress in the art was made subsequently until World War I, when increased loadings were found to be limited by high dielectric losses. This aroused active interest in decreasing the losses. However, with the new type of compounds and impregnation used for high-voltage cables, considerable trouble developed due to inherent weaknesses (mainly ionization) in the insulation.

Insulation Advances

Then, beginning in 1924, came an outstanding series of improvements in materials and methods of manufacture, which were of benefit also to some other types of equipment. Developments of paper-insulated cables have included shielding of insulation of three-conductor cables, oil-filled cable, various pipe-type cable systems, and self-contained gas-pressure cables.

Many new developments have been made also with other insulations such as changes in rubber insulations to make them more resistant to the effects of aging and ozone; development of synthetics to use in place of natural rubber; and changes in varnished-cambric insulation to obtain lower dielectric losses.

Conductors and Sheaths

The compact-conductor construction was introduced to obtain reduced size and other advantages, and the segmental-type was devised to reduce the skin effect for large conductors. Means and methods were developed to eliminate sheath losses in single-conductor cables.

Great advances were made beginning about 1932 in producing lead sheaths of sound integrity and of a high degree of concentricity. A recent development has been lead-alloy sheaths with improved mechanical properties.

Coincidentally, many better practices were introduced for (a) the installation of cable and accessories, and (b) the operation and maintenance of cable systems.

All of these improvements permitted some increases in the allowable temperatures for normal operation, and the cable fraternity became leaders in establishing much higher temperatures for use in emergency operation (See Fig 2).

Impregnated Paper-Insulated Cable—Solid Type

In 1924, the only paper-insulated cable in commercial use was the "solid" type. The change at that time from the rosin type of compounds to petrolatum compounds had resulted in cable, as manufactured, with sharply reduced insulation losses. The previous dielectric-loss characteristics were so high that they would have caused so much heating of the insulation on a

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with the collaboration of W. A. Del Mar, Phelps Dodge Copper Prod. Corp; C. T. Hatcher, Consolidated Edison Co of N. Y., Inc; L. F. Hickernell, Anaconda Wire & Cable Co; L. I. Komives, The Detroit Edison Co; A. D. Pettee, General Cable Corp; G. B. Shanklin, General Electric Co; R. J. Wiseman, The Okonite Co

69-kv cable that practically no load current could be safely carried.

Then troubles developed due to ionization, ie, electric discharges in void spaces or gas pockets. Although vacuum treating processes were used in the impregnation of the cables, the final structure was not wholly free from gases, and void formation resulted from volumetric changes with load variations. The petrolatum compounds proved to be susceptible to attack by ionization, with resultant operating troubles.

Research Initiated

A number of large operating companies set up research projects in their own laboratories, and under industry sponsorship, in university laboratories, all in order to supplement the work being done by the manufacturers and to intensify the attack on a number of very pressing problems.

Among the early developments was a shift from petrolatum compounds to cylinder oils (already started in Europe), major improvements in evacuating and impregnating techniques, and greater attention to uniformity of manufacturing processes. Change from manila paper to wood-pulp paper produced insulation with higher dielectric strength. Improved taping machines and methods resulted in more smoothly and compactly applied tapes. Indications of the resulting improvements are given in Fig 3.

An important development for three-conductor cables was brought from Europe. In belted-type cable there are large electrical stresses in directions parallel to the surface of the tapes which are a source of electrical weakness, especially at the higher voltages. By covering the insulation of each conductor with a metallic tape or shield, all the electrical stresses are made radial and the deterioration correspondingly reduced. Also, tests indicated an increase in the permissible operating temperatures. The shielded construction is now common, too, for other types of insulation, particularly above 5 kv.

About 1939, the industry began to use semi-conducting paper tapes (carbon-black impregnated) or metallized paper tapes over the conductor and over the insulation to overcome the effect of strands on the electric stresses and to act as a barrier to any deteriorating compounds that might form outside the paper insulation. The principles of this practice were soon adopted for other insulations.

Paper tapes of varying density or thickness have been used in all types of paper-insulated cables in order to modify the distribution of stress or to give higher dielectric strength in regions of higher stress.

Reduced Insulation Thickness

Along with these factory changes, improvements in field methods were occurring with the overall result that large reductions in insulation thickness became feasible. For instance, for 4-kv, belted-type cable the conductor insulation has been reduced from about 155 mils to 85 mils, and for 12-kv, shielded-type cable the reduction has been from about 205 mils to 150 mils. Another result is satisfactory three-conductor, 33-kv

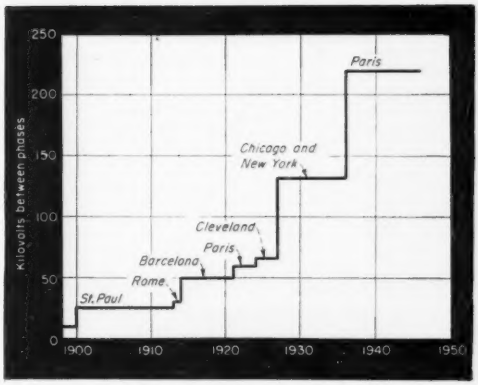


FIG 1–MAXIMUM OPERATING VOLTAGES in use for underground cables. (Data for entire world)

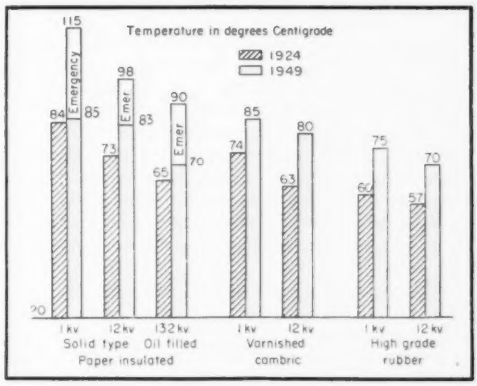


FIG 2–RECOMMENDED MAXIMUM operating temperatures. The base line represents the usual assumption of a base-earth temperature of 20 C. Allowable conductor temperatures shown are those given in the prevailing standards. For VC and rubber insulations, higher temperatures now are sometimes used for emergency operation, but are not included in the standards

cables with large conductors that can be installed in 3½-in or 4-in ducts.

In 1924 there was an urgent need for a type of cable design that could operate satisfactorily at 110 kv and higher. The oil-filled cable being developed abroad appeared to cover this requirement, and the first commercial installations were 132-kv lines that went into service in 1927.

The purpose of this design is to keep the oil free of gas, void spaces, and moisture and under positive pressure at all times in service. This is achieved by means of oil channels in the cable and by the use of a thin oil. The channels permit the factory impregnating processes after the lead sheath is applied. In the installation the cable is connected to sealed reservoirs that compensate for thermal volume changes of the oil. Usually the maximum internal cable pressure is about

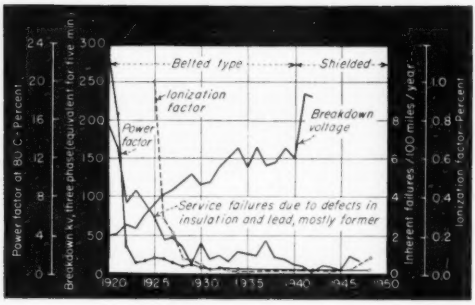


FIG 3—IMPROVEMENTS in 3-conductor, 12-kv cables. Results of factory tests are for one make and failure rates are for the several makes furnished one utility

15 psi. The resulting required insulation thicknesses are about half those of solid-type cable.

Operating Experience

Over the years, the insulation thicknesses for oil-filled cable have been reduced by about 20%. An important factor affecting these thicknesses is the required impulse strength. Oil-filled cables have been used generally at 66 to 132 kv (two 220-kv installations exist in France).

The operating record has been very good. Of the few failures that have occurred, none have been due to any deficiency in the cable insulation. Initial maintenance expenses for oil-filled cable installations were high some 20 years ago, but for recent installations these costs have been small.

Pipe-Type Cable Systems

Pipe-type cables of various designs were developed to overcome the ionization problems in a new manner, mainly to obtain more simplicity and in some cases less cost than with oil-filled cable systems.

Three single-conductor cables for a line are installed in a steel pipe, which is then filled with either nitrogen or oil maintained at about 200 psi in order to keep the oil or gas in the insulation under compression. Some economy is obtained by using unusually long lengths between joints.

Protective Sheath

The first pipe-type system was put into commercial service in Europe in 1932 and in the United States in 1934. The first type used here (still used) had solid-type cable insulation and the pipe filled with oil. To protect the cable during shipment, a lead sheath which was removed during installation was applied over the outside of the skid wires that are over the insulation to facilitate pulling into the pipe. Recently, however, special tapes have been applied over the insulation and weathertight reels employed to make it feasible to ship the cable without a lead sheath.

At the present time a variety of pipe-type cable designs are available. The gas or oil in the pipe is either in contact with the insulation through paths between turns of the outside protecting tapes or the installed cable is self-contained, that is, it has an outer sheath of lead or polyethylene. Round conductors are used, except for the cables with a sheath outside the insulation where the conductor is slightly oval.

Thermal Characteristics

The insulation thicknesses of pipe-type cables have been set the same as for low-pressure, oil-filled cable, except that greater thicknesses have been used in some cases for cables with gas in contact with the insulation to limit the maximum stresses to a predetermined value.

Recently there has been increased interest in assumptions and calculations used in determining the carrying capacities as affected by the thermal characteristics of an installation and by the losses in the conductor, metallic shielding tape, skid wires, and pipe. The ratio of the total of these losses to the d-c losses increases rapidly with conductor size, and now limits the maximum economic conductor size to about 2,000,000 cm. Research on determining these losses, and on methods of minimizing some of them, is under way. Other development work has been concerned with accessories and methods for locating failures and pipe leaks.

Self-Contained Gas-Pressure Cable

When a hole develops through the lead sheath of a cable with solid-type, varnished-cambric or rubber insulation, no indication is given to the operator until the cable fails. For oil-filled cables, signal systems show loss of oil that would occur with a hole. The self-contained gas-pressure type of cable was developed partly to obtain a simple system that would give the operator an immediate indication of holes.

The first cable of this type appeared 10 years ago and operates at about 12 psi.

Insulation thickness for a given voltage is between the amounts specified for solid-type and for oil-filled cable. This type of cable has been installed for operation at 11 to 42 kv.

As the internal pressure is increased, the stress at which ionization starts is increased. For the next higher range of voltage, such as 66 kv, the self-contained gas-pressure cable is designed to operate at about 45 psi and has a reinforced (or alloy) sheath. For voltages such as 132 kv, the pressure is 200 psi and the reinforcing for the cable and accessories is stronger. The first installations at these two pressures are to go into service some time this year.

Rubber and Varnished-Cambric Cables

Some rubber or varnished-cambric insulated cables have been installed in ducts for operation at medium and moderately high voltages. The combination of the relatively lower temperature limits and higher cable costs for a given conductor size results in a higher cost per kva of circuit capacity than for paper-insulated cables.

Nevertheless, there are definite uses for such cables, particularly in the medium-voltage class (also in low-voltage class). The terminations and joints are somewhat simpler because no air-tight, moisture-proof cover-

ing need be applied. The result is considerable usage inside buildings at 2,300 and 4,000 v and in some cases at 13 kv.

Aerial and Buried

Both types of insulation, especially rubber, have been frequently used in the past several years for aerial-cable distribution, generally at about 4 kv. The single conductor or the three conductors are either attached to a messenger at the factory or in the field.

Rubber-insulated cables without lead sheath are of particular interest for buried installations to operate at about 4 kv or less. Another application is in submarine cables of various voltages up to 33 kv where the cable is covered with a steel wire armor.

Varnished Cambric

For varnished-cambric insulation, new compounds have been introduced to reduce somewhat the dielectric losses that obtained with the asphaltic varnish and to allow higher operating temperatures. Improvements have taken place in factory methods which increase uniformity in properties and reduce the air and moisture entrapped within the insulation, thereby increasing the dielectric strength.

Synthetics

Many variations in types, properties, and qualities of synthetics have appeared in the past 15 years. Some are used considerably as a substitute for natural rubber in insulating compounds. Some were designed mainly to gain operating advantages, such as resistance to oil or chemicals. Synthetics have been developed for use as tough jackets in place of rubber or weatherproof braids, an outstanding example being neoprene.

Synthetics developed during World II for use in place of natural rubber were at first irregular in quality, but before the war ended they had attained uniform good quality.

Polyethylene

Polyethylene was developed and it has very low dielectric losses and high dielectric strength. It has been used for high-voltage radar leads and to a limited extent for medium-voltage power cable. Polyethylene has a high coefficient of expansion and becomes very soft at about 110 C.

Another new synthetic is butyl "rubber", which has high temperature limits for operation and excellent ozone resistance. These and other properties have caused interest in its use at 2 to 15 kv.

Allowable Temperatures

Since 1924 allowable temperatures for normal operation for power cables have been increased considerably (Fig 2), thereby permitting higher carrying capacities. In many cases the temperatures are considerably above those permitted by foreign standards. Also, limits for emergency operation have been established for paper-insulated cables.

The increases in allowable temperatures for all types of insulation have become possible through improvements in the manufactured products and on the basis of accelerated aging tests made by the ultilities and manufacturers.

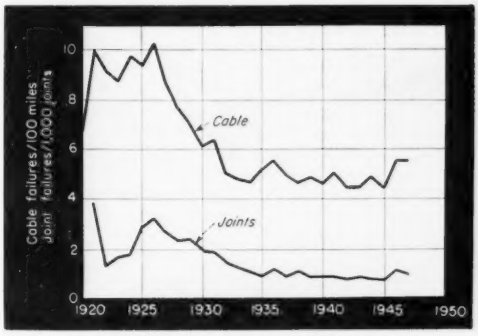


FIG 4—RATE OF SERVICE FAILURES in high voltage lines (Data from NEMA and EEI reports)

Sector and Segmental Conductors

In order to effect a further reduction in the amount of materials required, to make the conductor surface smoother, and to reduce a-c losses slightly, the practice of compacting the sector-shaped conductors for multi-conductor cable was started about 1932. This practice was extended in some cases to round conductors also. The reduction in conductor dimensions is about 10%. Large single-conductor cable with compact conductor is somewhat springy in connection with training in manholes.

In the early days the high ratio of a-c to d-c resistance losses in extra large conductors was reduced by using a rope center. About 1931 the segmental type of conductor was developed to obtain reductions in a-c losses with less cable cost. The conductor consists of three or four stranded segments, usually four, with the segments insulated from one another and an overall metallic tape.

Aluminum

Some consideration has been given to the use of aluminum instead of the usual copper conductors for underground power cable. The problem of jointing aluminum has been fairly well solved and some cable with aluminum conductors has been used. The increased size of adequate aluminum conductors and resulting increase in cable size has retarded the adoption of aluminum conductors. Also, the relatively large coefficient of thermal expansion of aluminum accentuates problems with cable movement in manholes.

Metallic Sheath Coverings

Due to its flexibility and ease of application in manufacture and generally long life, lead has long been used as a sheath covering for insulated cables as protection from the effects of air and moisture. It also provides a metallic return for fault currents.

In 1924 all insulations were such that the internal cable pressures developed upon heating were insuf-

ficient to cause appreciable sheath stretching. However, with the use of oil-filled joints on high-voltage solid-type cable, there was a tendency for the joint oil to migrate permanently into the cable insulation. The result was that the sheaths gradually stretched to produce cracks, first at places containing dross, and later at unusually thin spots in the sheaths as made.

Improved Lead Sheaths

Beginning about 1930, manufacturers introduced a large number of developments to produce (a) sheaths free of dross and weak welds, and (b) sheaths with variations from average thickness of about 5%, instead of the 15 to 30% variations that had previously been common. The result is that we now have sheaths which appear to be the soundest and most concentric produced in the world.

In determining the load capabilities inherent in cables, particularly for paper-insulated cables, it has been found that the "bending" life of the cable sheath in manholes until cracking occurs may be only 1/3 to 2/3 the life inherent in the insulation. This cracking is the result of the small daily bending in the manhole caused by the longitudinal expansion and contraction of the cable in the duct with varying load.

This unbalance in design called for the development of lead-alloy sheaths. A few were tried experimentally and found to be age hardening and lacking in ductility. Starting in 1945, some new alloys of the arsenical type possessing the desired properties became available, and are being used commercially. According to tests, their life until fracture in manhole bending is 2½ to 5 times as much as for ordinary lead sheaths. Sometimes alloy sheaths also permit cable training in small manholes without premature failure. Other advantages are the relatively high allowable hoop stresses for alloy sheaths and increased abrasion resistance.

Sheath Coverings

Failures due to corrosion in certain locations have increased interest in protective coverings over lead sheaths, and the recent high costs of lead have stimulated some interest in reduced lead sheath thicknesses with jackets.

The early coverings usually consisted of a few fabric tapes coated with asphalt. More recently, built-up jackets of neoprene and fabric have been developed. These are more substantial and cost more. Other types of covering have been used. The life of modern nonmetallic jackets seems to be at least 15 years, perhaps 2 or 3 times that, subject to future experience.

Installation and Maintenance

Operating experiences of about 25 years ago, especially when the voltages were being increased for underground circuits, demonstrated the need for improved field methods. There were many failures in joints and potheads, and some failures in cable due to lack of appreciation by the field forces of the effects, for example, of moisture and cuts in paper insulation in joints.

Changes were made in the designs and materials for the accessories, and much testing was done. Lectures and other methods were used to help workmen do a better job. Also, technical inspectors were employed for field work for the higher-voltage installations. In one case, the result has been a reduction from twenty joint failures to one failure per 1,000 joints per year due to all causes for 12-kv, 3-conductor joints.

Changes were made in the design of ducts and conduits to avoid sharp edges between adjacent lengths of duct and to avoid sumps, which have caused some sheath corrosion. Manholes were enlarged and the cable training was improved. The cable was protected to eliminate the quick wearing of the sheath due to friction with daily movement at the edge of the duct in the manhole. Methods of installing and supporting joints and potheads were changed to make them permanently tight.

The net result has been impressive improvements in the physical condition of the cable and joints and potheads as installed, and a good decrease in the rates of failures due to workmanship and "unknown" causes.

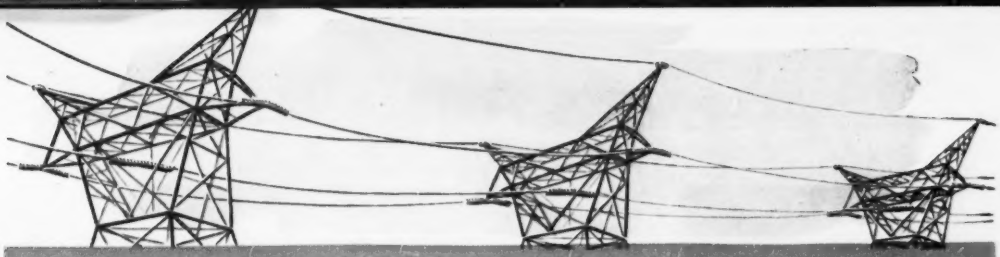
The Future

Although the progress relating to power cables has been highly gratifying in the past quarter of a century, partly indicated in Fig 4, much remains to be done. The chief impetus is economic pressure, because costs of cable and of means and methods used for installation have increased 50 to 150% in the past decade. This condition establishes also the need for detailed studies of available designs of cable and accessories and of installation techniques, in order to obtain the most economic installation feasible in each case.

Problems ahead include the following, all of which have received some attention: Lowering the a-c resistance for large conductors, especially for pipe-type cables; improving the stability of impregnating oils; low vs high-viscosity oils in gas-filled pipe cables; reduction in paper-insulation thicknesses, especially for extra high voltages; developments on synthetics to obtain improved operating characteristics; and lower-loss and more uniform varnished-cambric insulation.

More problems are: Improvements in physical properties and uniformity of lead alloys; reduced costs for satisfactory materials and constructions for use partly or entirely in place of lead sheaths; reduction of thicknesses of lead sheaths without jackets; demonstration of non-metallic jackets for buried cables having 35-year life; improved construction of solid-type paper-cable risers; taking care of the movement of pipe-type cables and buried cables; reduction in variety of designs of pipe-type cable systems; commercial developments of cable and accessories for operation at 230 kv and above; and development of less expensive test methods, especially for accelerated-aging tests.

Further problems with particular reference to users are: Increased usage of the higher load capabilities inherent in various types of cables, especially for emergencies; reduction of rate of failures due to non-inherent causes; increased use of aerial and buried cables; reduction in costs of conduits and manholes; use of longer cable lengths; and attainment of increased cable occupancy of existing conduits.



HOW LOCKE'S WET-PROCESS PORCELAIN INSULATORS HAVE CONTRIBUTED TO THE GROWTH OF POWER TRANSMISSION

The First Wet-Process Porcelain Insulators

In the late 1880's Fred Locke designed a new type of glass insulator that would function under adverse weather conditions. By 1888 many thousands of the new insulators had been sold, but the progress of power transmission was swift, and in the early 90's Locke decided that glass insulators had definite limitations, so he turned to dry-process porcelain.

Again many insulators were made according to his design, but Locke still felt a different type porcelain was necessary to make a dense, non-porous body that would not crack under temperature changes. This led to his invention of the first wet-process porcelain insulators.

PUNCTURE-PROOF, LEAK-PROOF PORCELAIN MADE

The development of the new wet-process porcelain was rapid. Locke found a way to utilize the valuable insulating qualities of quartz by grinding it and adding feldspar for re-fusion, plastic clay to facilitate molding. When this mixture was burned at a white heat, Locke found that he had the basis for a puncture-proof, leak-proof porcelain insulator that would withstant violent temperature changes.

In 1894 Locke established his own plant at Fishers, New York, where he continued to improve his wet process porcelain. One of his first customers was the John Martin Company of California, whose proposed 60,000 volt transmission line was made possible by Locke's new wet-process porcelain insulators. These insulators cost the John Martin Company just $1.00 apiece, and were so successful that they endured for 25 years, requiring replacement only when the line was converted to a higher voltage.

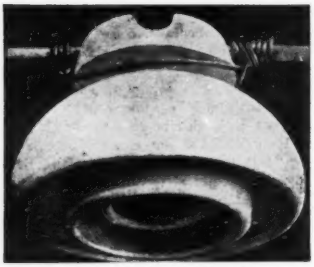
TESTING LABORATORY BUILT

To make further research and development possible, in 1904 Locke built the most powerful testing laboratory of the day. It consisted of a transformer with a capacity of 200 KW at 300,000 volts and a top potential of 400,000 volts. An experimental pole line was also employed, and means were provided to adapt and space any style pin or insulator.

A simple dynamometer provided facilities for testing tensile and crushing strengths of insulators and insulating materials, and an electric furnace was installed to enable study of refractory substances. Also, there was a complete chemical and ceramic laboratory, since insulator design and manufacture were so closely allied with ceramic and electrical development.

before you buy.. stop! see what LOCKE'S got...

THE DEVELOPMENT OF LOCKE



The first triple petticoat insulator

Early Developments

In the issue of January 4, 1896, ELECTRICAL WORLD announced a major improvement in insulator design—Fred Locke's triple petticoat insulator. It was 5½ inches in diameter, 4 inches high, and had a flashover value of 85,000 volts. In the issue of October 9, 1897, a second article announced the helmet-type insulator, which had a trough and spout to conduct water out over the crossarm thus providing improved flashover characteristics.

The Helmet type insulator

A third development was the porcelain base pin, which, when installed, had the effect of placing another insulator between the insulator and the pin, thereby increasing the flashover value.

Suspension Insulator Introduced

In 1903, designers of transmission lines, facing the acute problem of pole shortages, experimented with steel towers, and in that same year, the Guanajuato Transmission line in Mexico used this new construction.

At this time Locke found the answer to higher insulation levels— the suspension insulator—which made it possible to operate at the unheard of voltage of 100,000.

The first flexible suspension units consisted of two types: the Duncan cap and pin type unit with clevis connection, and the Hewlett type with interlocking hardware. Though the cap and pin types could be produced at far lower cost, the Hewlett type was preferred because it did not require cement. Locke's development of physically and chemically stable cement changed this picture, and by 1930 the cap and pin type was firmly established.

The first suspension insulator

Locke Hewlett type suspension insulator

Cement Space Gap Introduced

The early suspension insulators had caps cemented to the porcelain with the lower edge of the cap resting on the porcelain shell. To prevent "dough-nutting" from sudden temperature changes, Locke developed an assembly that had a space gap between these members. This gap is now standard on all suspension insulators, regardless of make.

First High-Strength Insulators

In 1910 a limiting factor in the proposed electrification of an important railroad was the lack of suspension insulators that were strong enough yet small enough to allow practical construction. To meet the problem, Locke developed the first high-strength suspension insulator. Today, 85% of all the world's railroad electrifications use Locke suspension insulators.

Among the earliest single and stacking type insulators were two insulators that have been outstanding—Locke No. 8888 and No. 7785. 28 years ago Locke No. 7785 was generally recognized as the standard for all outdoor high voltage switch and bus service. Today—fundamentally unchanged—this unit is still the first choice of operating engineers and designers.

The first Locke grading shield

By 1922, the ever-increasing demand for Locke insulators forced the move to a larger plant. The present site at Baltimore which offered plenty of room for expansion among many other advantages, was chosen as ideal.

The famous Locke 7785

Hi-Top Insulator Designed

During the depression, Locke designers initiated a program to completely review

Hi-Top insulators

before you buy.. stop! see what LOCKE'S got...

HIGH-VOLTAGE INSULATORS

Insulator showing location of sand grip

all insulator designs from the smallest to the largest units. Many improvements were made—one of which was the introduction of the now famous "Hi-Top" insulator.

In the early 30's the laboratory staff of the Locke Insulator Corporation perfected "Compression Glaze," which made available insulators of greatly improved mechanical characteristics. Impact strengths were far in excess of anything previously considered possible.

Continuation of this research showed the need for an improvement in "sand grips," by means of which insulator parts are assembled. After much testing, the Locke laboratory developed a new compression sand that provided the answer. Formerly, the edge of the sand band was the weakest part of the insulator. Today, with the use of Locke compression sand and compression glaze, it is by far the strongest.

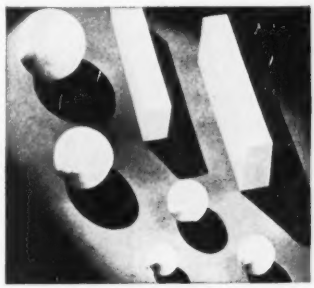
Related Products

Pole Line and High-Line hardware were sold by Fred M. Locke when he first started in business in 1894. His catalog of 1896 showed a complete line of hardware and distribution materials. Today Locke is one of the largest suppliers and manufacturers of all types of Insulators and Pole Line Hardware, as well as associated material for all types of transmission, distribution, station and power applications.

Apparatus porcelain

As transmission and distribution voltages increased, a need arose for related porcelain products other than line insulators. To answer this need, Locke manufactures a line of apparatus porcelain—such as housing for lightning arresters, cut-out boxes, bushings for circuit breakers, cover and pocket bushings, and a great many porcelain components for assembly into complex electrical devices.

In 1930 Locke application research found that wet-process porcelain products could be applied to good advantage in the manufacture of porcelain enamel and paints. Locke porcelain bricks and balls were readily adopted by the industry, and today their manufacture is an ever increasing business.



Bricks and balls used in ball mills

NEW PRODUCTS DEVELOPED BY LOCKE DURING THE WAR

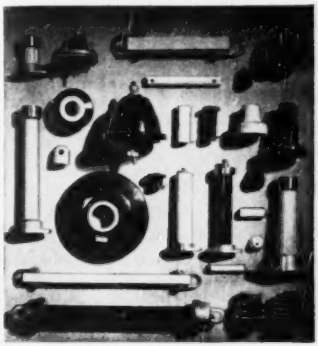
During the war years Locke supplied millions of ceramic and hardware parts to the armed services. Some of these products were:

Mast Base Insulators—used in the bases of antennae of military vehicles. Locke developed a new process, manufactured hundreds of thousands of these bases at a cost of less than half that of the previous methods.

Porcelain Cross Arms — Locke developed and produced a cross arm from glazed, wet-process porcelain that solved the Signal Corps' need for a means of carrying radio frequency leads from transmitter to antennae on overhead construction.

Special Radio Insulators—Locke was the chief source of supply for special insulators used for supports on high powered radio stations. Manufactured in lengths up to 17 feet—they were the longest porcelain pieces made.

Hermetic Sealing of Porcelain—Locke developed one-piece porcelain terminals and transformer tops with provisions for soldering the metal parts directly to the ceramic. This method contributed much to satisfactory radio performance under adverse weather conditions.



War products

Zircon Bushings—When the atom bomb development was underway at Oak Ridge, Locke developed special zircon bushings and stand-off insulators that could withstand high and sharply changing temperatures, and exposure to ionic bombardment.

Telephone Insulators—A small telephone insulator was developed with a screw-threaded pin cemented into the insulator for use on temporary telephone and telegraph wires.

Mobile Antenna Strain Insulators — Locke developed a special pressed Steatite insulator which made it possible and practical to insulate and secure the spike antenna on army vehicles. Almost a million of these units were produced at about 25% of the cost of the former insulators.

Rhombic Antenna Kits and Strain Insulators—One of the most critical items needed for troop radio communication was the Rhombic antenna strain insulator. In order to supply vast quantities of these quickly and at reasonable cost, Locke developed the wet press method of forming wet process porcelain in steel dies.

before you buy.. stop! see what LOCKE'S got...

LOCKE'S FUTURE IN CLAYRAMICS

The Fred M. Locke Ceramic Research Laboratory

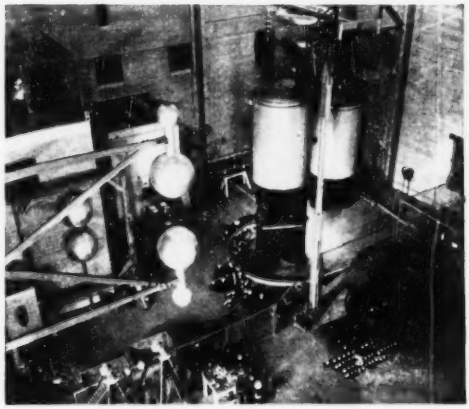
Locke is doing fundamental research in the entire field of ceramics in an effort to discover new and better materials that will have the necessary characteristics—electrical, mechanical, chemical and thermal—to give maximum performance in their respective applications. In conjunction with the control and processing of raw materials, Locke intends to produce porcelain and other ceramics by scientific and highly mechanized methods.

LARGEST CERAMIC RESEARCH LABORATORY

To help accomplish these objectives Locke built the Fred M. Locke Ceramic Research Laboratory, has equipped it with the most modern tools of research, and has staffed it with experts in the ceramic field. In addition, Locke's design and development engineering divisions have been greatly enlarged and staffed with competent engineers who will apply the results of the research laboratory to existing as well as new products. The new Ceramic Research Laboratory and the Reagan High Voltage Development Laboratory will provide tools and facilities for complete testing and research.

SERVE ELECTRICAL, CHEMICAL AND MECHANICAL INDUSTRIES

The laboratories are dedicated to the development of new and better materials; the uniform and scientific control of processing such materials; and improved and mechanized manufacturing process to provide lower costs, a wider range of applications for clayramics, and a greater diversity of products for Locke to better serve the electrical, chemical and mechanical industries.



The Frank H. Reagan High Voltage Laboratory

BALTIMORE, MARYLAND

before you buy.. stop! see what LOCKE'S got...

Experimental Talking Tower

FABRICATED AND ERECTED BY AMERICAN BRIDGE COMPANY

2-story Research Tower
f Federal Telecommunica-
ons Laboratories, Inc.,
utley, New Jersey. 300
et high, 38' —2" x 42' at
e base, it has 12 Main H-
olumns (4 inclined), joined
y angle and channel brac-
g, beams and girts. Weight
760 tons.

View showing completed project. Laboratory buildings were erected for Federal Telecommunications Laboratories, Inc. Buildings 1 and 2 (in background) Louis S. Weeks, Architect—George A. Fuller, General Contractor. Buildings 3 and 4 and Tower (in the foreground) Giffels and Vallet, Inc., Engineers—L. Rossetti, Architect—George A. Fuller, General Contractor. All structural steel fabricated and erected by American Bridge Company.

● Improved television. Multi-channel communication links. FM mobile communications systems. Radar aids to aerial navigation. These are a few of the projects already begun in the research tower and laboratory buildings which American Bridge Company fabricated and erected for subsidiaries of International Telephone and Telegraph Corporation in Nutley, New Jersey.

The same care, the same service, the same knowledge American Bridge used on this and many other projects are available to you whatever the size or complexity of your structural or erection requirement.

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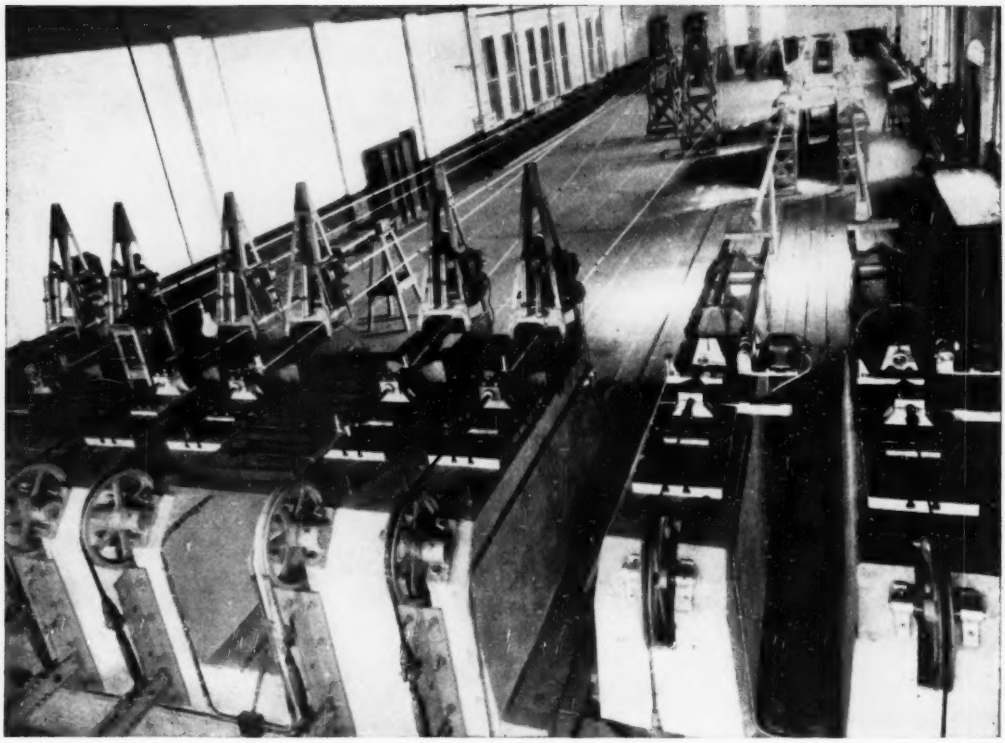
USS

AMERICAN BRIDGE

UNITED STATES STEEL



we tune the zephyr's bowstring

Utility men know how breezes can twang a cable—maybe to the point where the conductor fails from fatigue. You may not have known how Alcoa makes sure its ACSR stands up under that vibration:

In Alcoa's Massena testing laboratory, these machines give a cable the shakes, sometimes for years, in order to determine its fatigue resistance. Upward of 500 million cycles are needed to develop the endurance limit of aluminum.

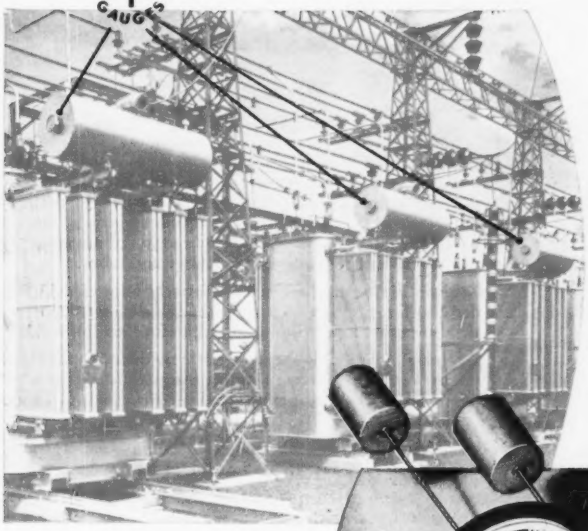
Alcoa research like this made ACSR a reality—now makes it superior. So superior that today eight out of every ten miles of line at 220,000 volts or more are ACSR.

What does that mean to you as a cable buyer? Just this: Alcoa ACSR has been proved and improved through more than 40 years of laboratory testing and installation experience. ALUMINUM COMPANY OF AMERICA, 2138 Gulf Building, Pittsburgh 19, Pennsylvania.

® ALCOA

ALCOA *Aluminum* CABLE AND ACCESSORIES

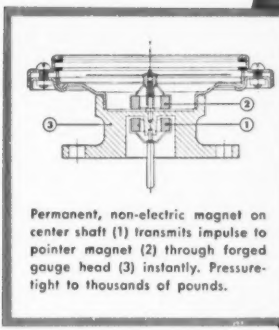
ROCHESTER ALARM GAUGES safeguard transformers Dependably

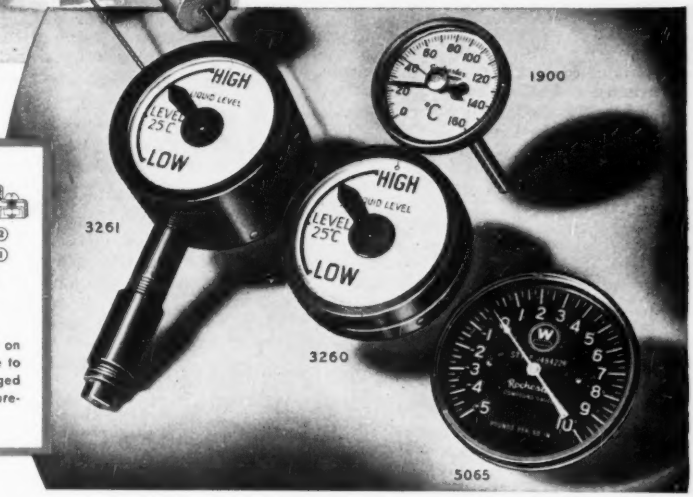


Transformers cost money. They can be ruined if oil level gets too low. That's why leading transformer manufacturers use Rochester Liquid Level Alarm Gauges. They have proved dependable for decades . . . stand up in fair weather and foul . . . protect your costly investment at small cost!

Rochester engineers pioneered the dial type, magnetic indicating gauge (see diagram) for oil filled transformers more than 20 years ago. Dependable and safe, it is used in many industries where inflammable liquids are involved. Consequently, gauges of this type are on your transformers today.

Present designs are compact, enclosing low level alarm switches within the dial chamber. The dial is readily removable for replacement in the field. Available with or without alarm systems, dial openings are 3¼" and 5½" in diameter.


Permanent, non-electric magnet on center shaft (1) transmits impulse to pointer magnet (2) through forged gauge head (3) instantly. Pressure-tight to thousands of pounds.



OTHER ROCHESTER GAUGES

Thermometers with 3", 4", and 5" diameter dials with or without maximum set hands.

Pressure and Compound Gauges with 3½" dial.

All Rochester Gauges are individually calibrated, provided with tempered glass crystals to eliminate breakage and are hermetically sealed. Specify Rochester Gauges on *your* transformers.

Rochester
GUARANTEED ACCURACY

ROCHESTER MANUFACTURING CO., INC.
75 ROCKWOOD STREET, ROCHESTER 10, N. Y.

ENGINEERED INSTRUMENTS

Liquid Level, Temperature and Pressure Gauges

Manufacturers of Fine Gauges for 34 Years

ANY WAY YOU FIGURE IT...

FIRST CHOICE IS..

FIGURED BY CIRCUITS... it's 4 to 1 (for generator leads—100%)

Here are the figures by circuits installed or under contract as of March 31, 1949:

Pipe-Type System	Transmission Circuits	Generator Lead Circuits
High Pressure Oil (Oilostatic Type)	43	23
Compression Oil	5	—
High Pressure Gas	10	—
Compression Gas	2	—
Total	60	23

A total of 83 circuits of all types have been purchased and, of these, 80% (66 circuits), are of the Oilostatic type. For generator lead circuits alone, 100% are of the Oilostatic type. Okonite-Callender has supplied 55 of the 66 Oilostatic type circuits.

FIGURED BY UTILITIES... it's 3 to 1

Here are the figures *by number of utilities* purchasing these systems:

Pipe-Type System	No. of Utilities
High Pressure Oil (Oilostatic Type)	19
Compression Oil	3
High Pressure Gas	3
Compression Gas	2
Total	27

A total of 25 separate power and light companies have purchased high-pressure pipe-type systems, one having as many as 12 separate circuits in operation. Only two utilities have installed 2 types of cable systems. Oilostatic-type systems, however, have been purchased by 19, or 3 out of 4 of these 25 utilities.

There are good reasons why Oilostatic* high oil-pressure pipe-type cable systems have become the preponderant choice of power and light companies within so few years. Oilostatic type systems offer a combination of advantages that increase circuit reliability, save money and labor.

Higher Dielectric Strength – entirely immersed in oil under 200 lbs. pressure to insure its high dielectric characteristics; no voids in the insulation, therefore no ionization.

Greater Simplicity – space saving: no ducts, no lead sheath; no riser cable problems; relieves congestion at points where overhead lines are impractical; also saves space in generator stations.

Easy Installation – all phases installed simultaneously in pulls up to 3600 ft; simple joints and terminals.

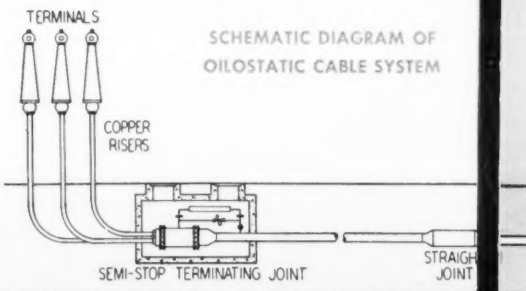
Broad Transmission Applications – highest current carrying capacity under emergency overload; no practical voltage limit; cables can be furnished for any present-day operating voltages.

Substantial Savings – when used in preference to a duct system, savings from 15 to 30% are obtained in city street installations; in open country 25 to 40% may be effected.

Same installation for land or submarine projects – unaffected by elevation, contour or nature of terrain.

Quick and easy to install, of rugged construction and requiring very little maintenance, dependable Oilostatic may be the answer to your problem. For complete installation and operating details, let an Okonite engineer consult with you. Also, for your information and help is Okonite's 16 mm. colored, "Oilostatic" film, supplemented by Oilostatic File Folder EW 75. Both are available upon request. Call or write to The Okonite Company, Passaic, New Jersey.

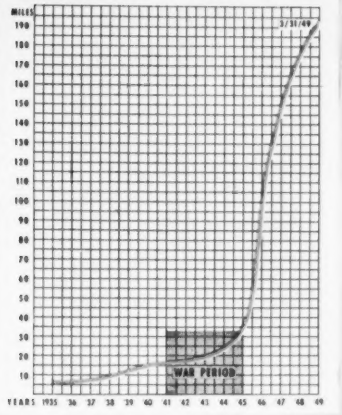
*"OILOSTATIC" is a registered trade-mark of The Okonite-Callender Cable Co., Inc. Other licensed manufacturers can supply this type system of power transmission by pipe line.



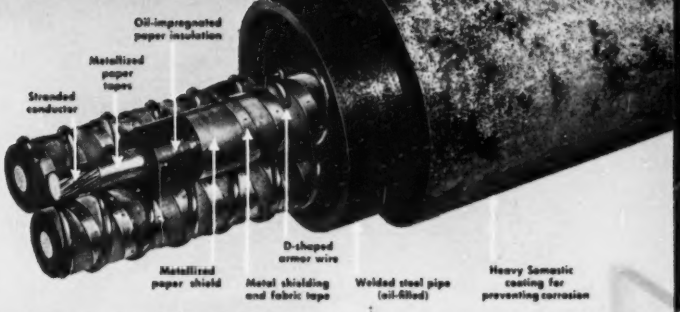
OKONITE-CALLENDER

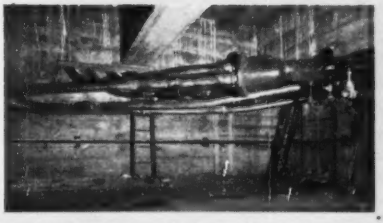
OILOSTATIC

HIGH-PRESSURE PIPE-TYPE CABLE SYSTEMS

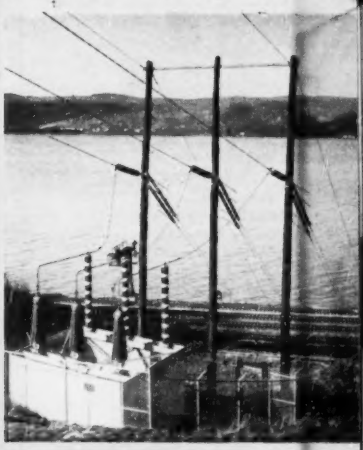


In 1939, there was only one commercial high-pressure pipe-type cable system in operation. This was the Pennsylvania Railroad's installation at Baltimore, developed and supplied by Okonite-Callender. In 10 short years, the total mileage of pipe-type cable purchased for operation at 100 kv. or over exceeds that of oil-filled cable, which was introduced in America 22 years ago.

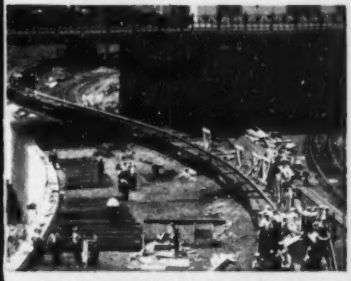




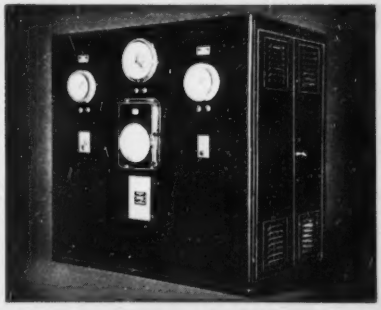
The first high-pressure pipe-type generator leads were manufactured by Okonite-Callender for the Burlington, N. J., station of the Public Service Electric and Gas Co. (1941), to obtain maximum reliability and space saving.



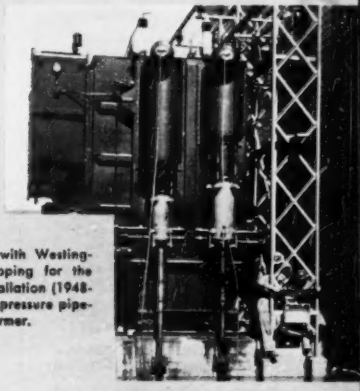
The first submarine crossing, utilizing a pipe-type system, was the 110 kv. Oilostatic cable placed across the Hudson River near Newburgh. All three cables were simultaneously installed in the 3400' pipe, the longest 3-phase pull on record.



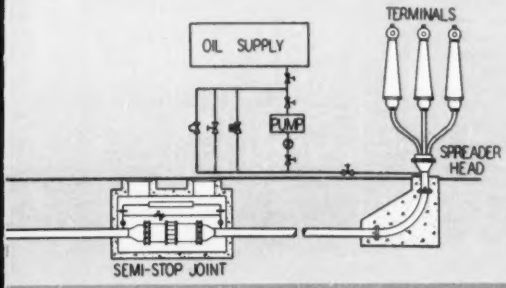
The first commercial high-pressure pipe-type cable installed in 1935 by Okonite-Callender for the Pennsylvania R. R. at Baltimore is a single phase 132 kv. Oilostatic system. This was also the first time 161 kv. high-pressure potheads had been used.



In Atlanta, Georgia Power Co.'s 115 kv. Oilostatic installation saw the first application of the cabinet-type packaged pumping unit originated by Okonite-Callender.



Okonite-Callender, in cooperation with Westinghouse, again pioneered by developing for the Alabama Power Co.'s Oilostatic installation (1948-1949) a method for connecting high-pressure pipe-type cable directly into the transformer.



HERE'S WHY NEOPRENE PRODUCTS DO SO MANY JOBS SO WELL

They resist
OXIDATION by air, oxygen, ozone—have outstanding resistance to aging.

They resist
HEAT—are exceptionally stable at temperatures up to 250° F.

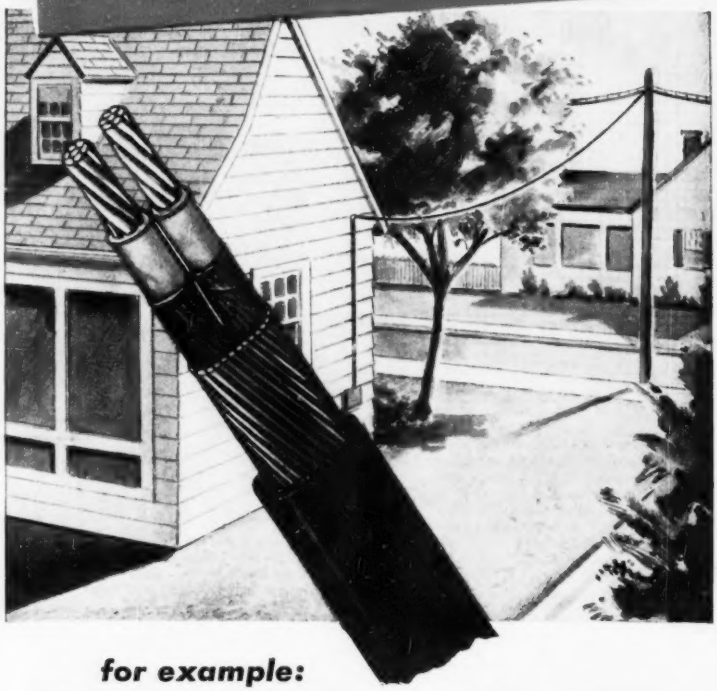
They resist
SUNLIGHT AND WEATHERING—in a class by themselves in resistance to rubber's worst enemies.

They resist
OILS, SOLVENTS, MOST CHEMICALS—set the standard for oil resistance throughout industry.

They resist
ABRASION, CUTTING, CHIPPING—are tough and durable under severe service conditions.

FREE! THE NEOPRENE NOTEBOOK—Interesting stories... new, unusual applications of neoprene. Write E. I. du Pont de Nemours & Co. (Inc.), Rubber Chemicals Division G-5, Wilmington 98, Delaware.

Better rubber products are made with Du Pont NEOPRENE



for example:

New neoprene-jacketed service entrance cable is designed for long, tough outdoor life

Here's a newly developed service entrance cable . . . designed to withstand season after season of severe outdoor conditions *without festooning*. Because it's protected with a smooth jacket of tough, durable Du Pont neoprene.

Before this cable was put on the market, commercial samples were submitted to the Underwriters' Laboratories for testing. And these are the results. Although heated to 70° C., the neoprene jacket didn't soften and drip. The cable was bent at low temperatures, yet no damage was sustained. And connector pull-out tests proved the cable held 3 times better than standard-design cables. In another test, a coil was wrapped for shipping, then cooled to -34.4° C. When the coil was dropped 8 feet to a concrete floor, there were no breaks or cracks in the neoprene sheath. And in an abrasion test, neoprene proved to be over 10 times more resistant than the conventional braided jacket. Since neoprene is inherently resistant to deterioration from sunlight and weather, it wasn't even necessary to conduct exposure tests.

With a record like this, neoprene-jacketed service entrance cable is equipped to take the worst kind of wear and *still* stay in service. It's another instance where neoprene adds to the service life and efficiency of cable. So insist on a neoprene jacket on cable you install. It means long life, low maintenance, fewer replacements.

Specify a jacket of

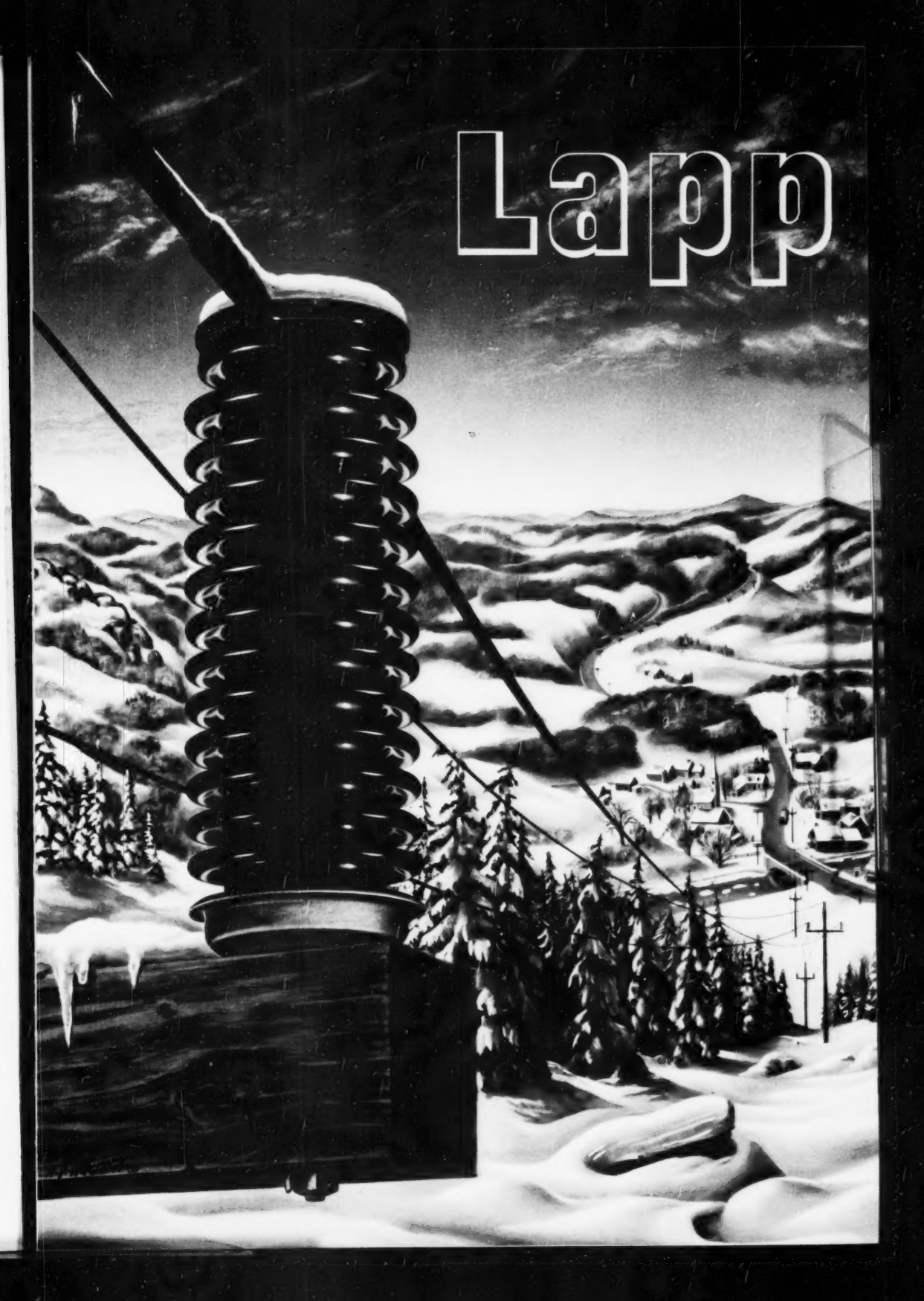
NEOPRENE

The rubber made by

DU PONT

REG. U. S. PAT. OFF.

BETTER THINGS FOR BETTER LIVING ... THROUGH CHEMISTRY


Lapp

Design and production of Lapp insulators have always been based firmly on a three-principle program... highest quality porcelain... severely tested... designed and assembled in such a way that it will endure.

The operating record of Lapp Line Posts and Station Posts has set a new standard by which high-voltage insulator performance must be judged. For eighteen years, hundreds of installations have been proving the fact that *lines on Lapp Line Post and Station Post Insulators have fewer outages than lines on any other type of insulator.*

LAPP INSULATOR CO., INC., LEROY, N. Y.

SIMPLEX-ANHYDREX CABLES

Through the Years—
A STANDARD OF DEPENDABILITY

Passing years bring many changes to the tools of industry . . . Necessary changes . . . Developments and modifications geared to keep pace with continuing world progress.

Simplex-ANHYDREX Cables have undergone just such changes.

Introduced to the electrical industry years ago as the first rubber-jacketed cables for burial directly in earth, they have ever since maintained leadership among underground cables.

But improvements in design have extended that leadership! Today, ANHYDREX Cables are unexcelled as 3-way cables, providing low-cost, trouble-free service when buried in earth, installed in ducts, or used in aerial runs.

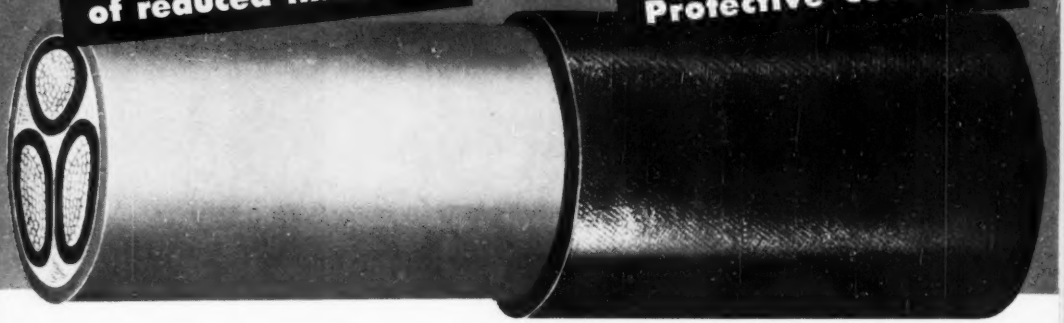
First in the past, first now, ANHYDREX Cables — backed by progressive Simplex research — promise to continue as the standard for comparison in the future. It will pay you to include them in your plans for tomorrow's power, communication, and signal circuits.

SIMPLEX-ANHYDREX

SIMPLEX WIRE & CABLE CO., 79 SIDNEY ST., CAMBRIDGE 39, MASS.

NOW COMBINED . .

OKOMETAL of reduced thickness PLUS OKOSHEATH Protective Covering



As a result of long, intensive study, the Okonite-Callender Research Laboratories have developed a further improvement in paper cable sheathing — *a composite sheath* of alloyed lead of reduced thickness reinforced and protected by a tough neoprene jacket that is bonded to it. Known as Okometal plus Okosheath Protective Covering, this dual sheath, at a price comparable with ordinary lead, is providing the 6 specific advantages shown above to a growing list of users.

OKOMETAL PROVIDES THE ANTI-FATIGUE COMPONENT

Okometal, an alloy of lead developed in the Okonite-Callender Laboratories, is designed to extend service life through its increased resistance to bending fatigue at joint offsets in manholes. Tests made with the dummy manhole machine described below clearly demonstrate that Okometal has double the fatigue resistance to cyclic bending possessed by ordinary lead.

COMPARATIVE MANHOLE BEND TESTS

Made on 3-conductor 500MCM compact sector cable with 0.150" insulation

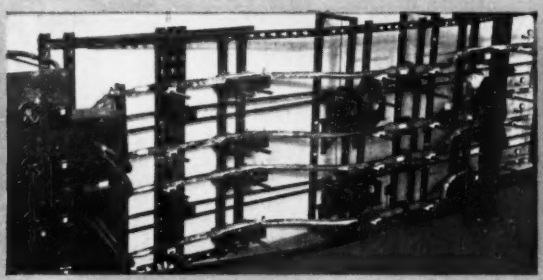
	Bend Cycles to Failure	Equivalent Life
With 0.120" standard AEIC lead wall	6,000	22.2 years
With 0.120" wall Okometal	16,000	59.2 years
With 0.080" wall Okometal plus Okosheath Protective Covering	16,000	59.2 years

OKOSHEATH PROTECTIVE COVERING ELIMINATES CORROSION

For over 15 years our Okosheath Protective Covering has been used by power companies to prevent lead sheath corrosion whether from chemical or electrolytic action. One user installed a length of cable in a duct where severe corrosion conditions were known to exist. Examination after 10 years showed the lead sheath and Okosheath Protective Covering were still in excellent condition.

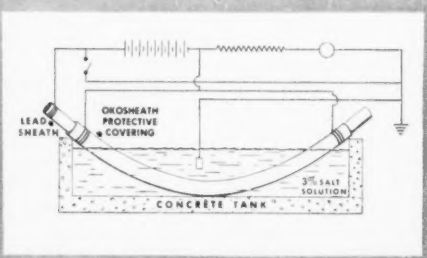
There is no recorded instance where lead sheath corro-

DUMMY MANHOLE MACHINE TEST



Lengths of completed cable with joints included are trained to standard contours and subjected to ½" movement at 4-minute cycles. Current application gives normal sheath operating temperatures. In this, and similar power company tests, 270 bending cycles are considered equal to approximately one year of actual service. Cables with Okometal of reduced thickness plus Okosheath Protective Covering outlast plain lead-covered cables 2½ to 1.

SEVERE SIX-YEAR TANK TEST

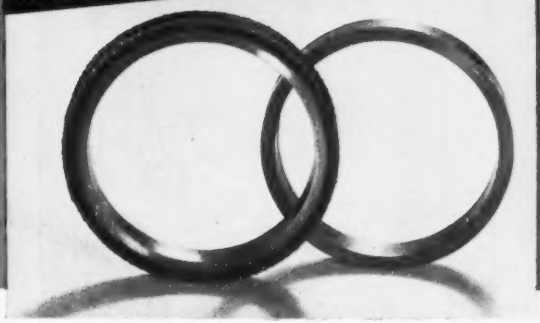


A section of lead-covered impregnated paper cable with Okosheath Protective Covering was placed in a 3% salt solution. Voltage continuously impressed between the sheath and the solution made the lead sheath positive. After six years in the tank, the insulation resistance from sheath to solution exceeded 250,000 ohms. The Okosheath Protective Covering showed no sign of deterioration and lead sheath was entirely free of corrosion damage.

OKONITE-CALLENDER

. . FOR LONGER CABLE LIFE

COMPARE THIS SUBSTANTIAL DUAL CONSTRUCTION WITH PLAIN LEAD OF SAME CORE DIAMETER.



YOU OBTAIN 6 MAJOR ADVANTAGES WITH THIS IMPROVED CABLE SHEATH

1. Doubles cable life expectancy
2. Eliminates chemical corrosion
3. Stops electrolytic damage
4. Prevents scoring of lead
5. Makes pulling easier
6. Reduces installation cost

sion has occurred in cables having our Okosheath Protective Covering. Sheath damage such as scoring during installation is also prevented by the Okosheath Protective Covering. Sixty-two per cent of all Okonite-Callender cables shipped in December, 1948, were made with Okosheath Protective Covering at the request of our customers.

OKOMETAL OF REDUCED THICKNESS PLUS OKOSHEATH PROTECTIVE COVERING IS THE COMPLETE ANSWER

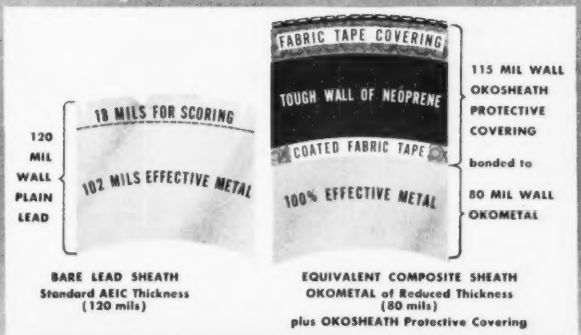
Tests show that Okometal by itself is twice as resistant to manhole bending fatigue as ordinary lead. Similar tests show that when an Okosheath Protective Covering is added, the Okometal can be reduced in thickness by one-third and still provide this same doubled life expectancy. A comparison of structural values (below) shows how *all* the sheath metal is effective when Okosheath Protective Covering is used and that no extra metal need be furnished for potential scoring damage. This reduction is also feasible because of the proved ability of Okometal to resist bending fatigue coupled with its higher bursting strength and excellent creep resistance.

Cables made with Okometal of reduced thickness plus Okosheath Protective Covering are easier to handle and pull because of their lighter weight and lower coefficient of friction. This suggests the use of longer cable lengths to reduce the number of manholes and joints.

In addition to all the operating advantages of Okometal of reduced thickness plus Okosheath Protective Covering from the standpoint of installation, maintenance and replacement, this new composite sheath extends by 50% the limited supply of lead available for cable sheathing. Such reductions in the use of lead will help to prevent further increases in the price of this scarce metal.

Comparative test results, explanatory photographs and diagrams, as well as more detailed data on this important development are available in Research Publication 110. Just write for your copy on your business letterhead. The Okonite Company, Passaic, New Jersey.

COMPARISON OF RELATIVE STRUCTURAL VALUES



With Okosheath Protective Covering, the 15% extra lead thickness normally required for scoring protection can be eliminated. The greater bursting strength, excellent creep resistance and increased resistance to bending fatigue of Okometal make a further reduction possible. Result: an over-all reduction of one-third in metal thickness still provides doubled life expectancy when this dual sheath is specified.

ELECTRICAL TESTS ON COMPLETED CABLE

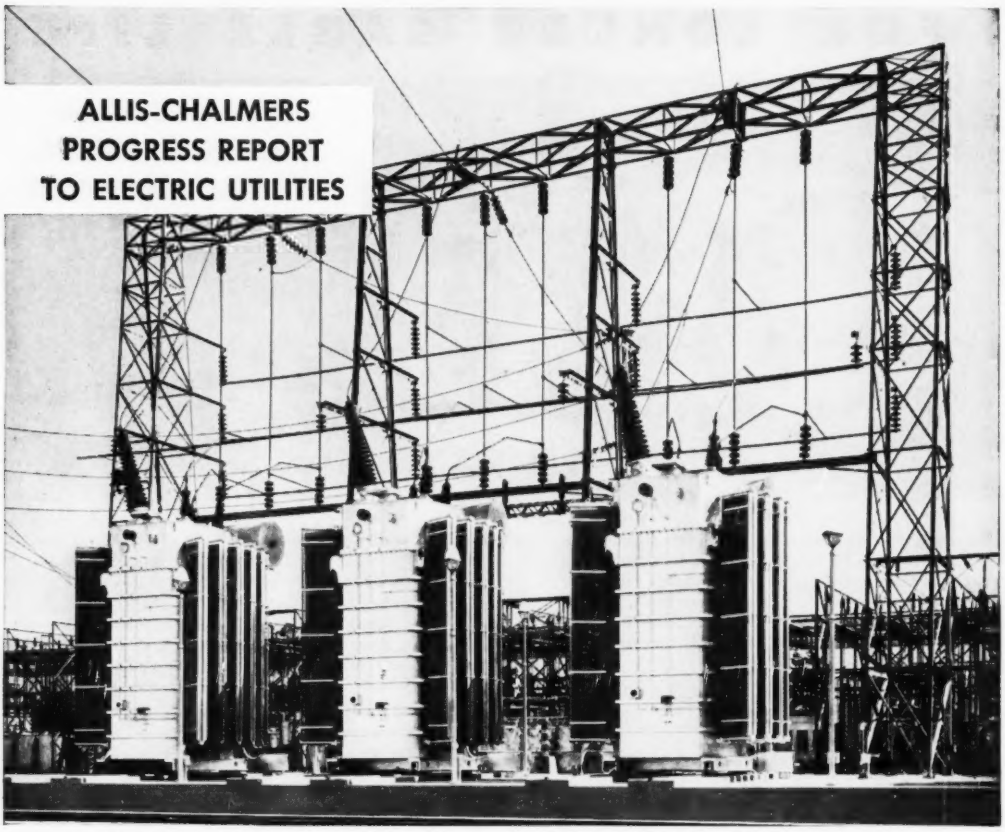
Finished cables made with Okometal of reduced thickness plus Okosheath Protective Covering meet all the electrical test requirements of the A E I C specifications for impregnated paper insulated cable made with plain lead and without the Okosheath Protective Covering.

OKONITE-CALLENDER

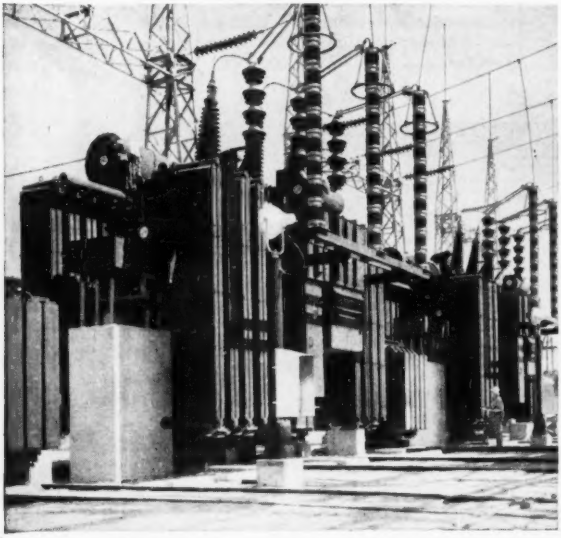
PAPER INSULATED POWER CABLES

7280

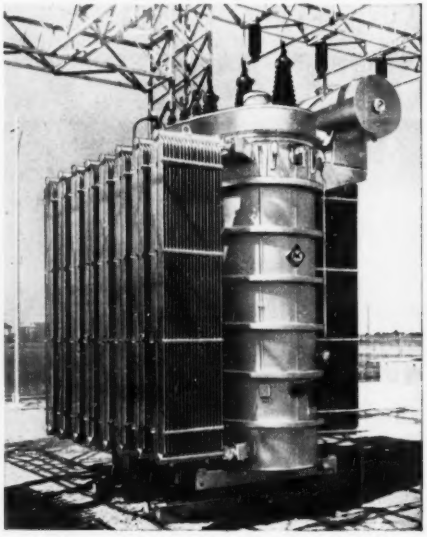
ALLIS-CHALMERS PROGRESS REPORT TO ELECTRIC UTILITIES



CALIFORNIA POWER COMPANY installation of 25,000 kva, 50 cycle, 127/230-72 kv, self-cooled, Load-Ratio equipped transformers



ILLINOIS—30,000/50,000 kva giants designed for 167% of self-cooled capacity



TEXAS—15,000 kva transformer; 20,000 with fans

Power Transformer Facilities Expanded, Deliveries Improved

INCREASED PRODUCTION resulting from expansion programs at A-C transformer plants in Milwaukee and Pittsburgh is making it possible for Allis-Chalmers to supply the nation, still running close to the critical mark in system loading, with increasing numbers of transformer units.

G. W. Clothier, Mgr., West Allis Transformers, F. V. Regulators

During the past year, major Allis-Chalmers power transformer advancements included:

1) Shipment of several large 2500-kva, 110-kv portable substations . . . the largest of this high voltage ever built.

2) Installation of hydrogen annealing facilities for processing of preferred oriented core steel. Ultimately this will mean more efficient, lighter weight or lower cost transformers. For the present it is helping to alleviate a critical steel shortage.

3) Introduction of dielectrically molded, corona-free—practically deterioration-proof — insulation, further ensuring A-C's enviable record.

4) AIEE impulse tests on over 85% of large, high voltage power transformers for more sensitive detection of insulation faults.

5) Construction of one of the largest transformers of all time. Rated 40,000 kva, 3-phase Wt. 380,000 lbs.—an even larger one to be built shortly.

Allis-Chalmers' redesign program on units in the 500-10,000 kva range, 66 kv and below produced a number of significant engineering advancements, including: more efficient use of insulation; reduction as much as 15% in dimensions and weights of certain ratings; new bushing designs, enabling assembly from standardized unit parts without need for cementing — greatly simplifying field replacement.

In addition, certain designs of tanks have been developed to withstand full vacuum through more efficient bracing. Better surface protection on individual radiator assemblies is ensured by dip-bonderizing before painting. And A-C's famed positive pressure inert gas sealing has been further simplified reducing cabinet size by half.

J. W. McMullen, Gen. Mgr., Pittsburgh Works, Transformers

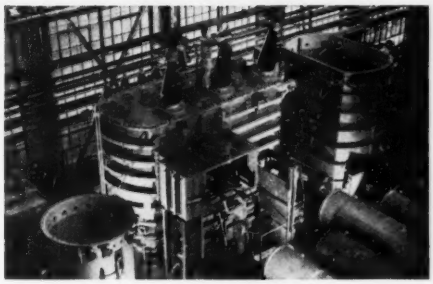
★ ★ ★

On Allis-Chalmers power transformers — 500 kva to the largest *installations* prove the quality. Check our service records in every part of the country. Check our transformer experience—50 years of it, combining good design, quality material and premium workmanship to increase transformer life span, lower maintenance.

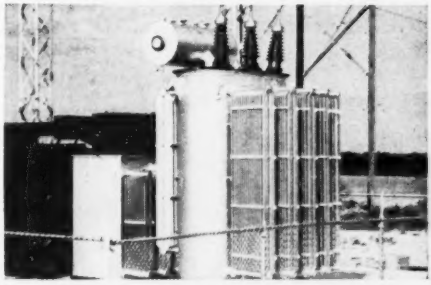
A-C *originated* the Oil-Sealed Inert Gas system—that operates without delicate valves and at pressures under one pound. A-C *pioneered* Load Ratio Control to achieve economical, low maintenance voltage regulation or phase angle control . . . double disc coils on smaller power transformers, and No Load tap changer through tank wall.

In many ways Allis-Chalmers has pioneered quality features in modern power transformers . . . quality that is backed up by nation-wide installation records! ALLIS-CHALMERS, 932A, S. 70TH ST., MILWAUKEE 1, WIS.

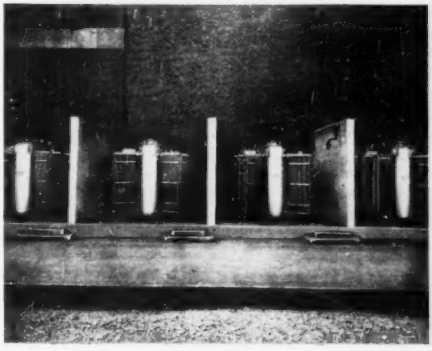
A2718



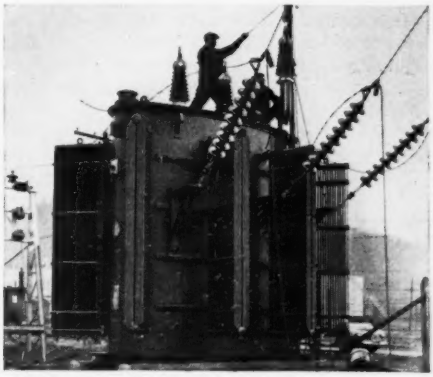
ASSEMBLING 30,000 kva, ± 10% LRC, unit for Midwest



4500 KVA, 69-12.4 kv unit steps-down v. to switchgear



FOUR 4000 kva, 3-phase power transformers, Midwest utility



INSTALLING 10,000 kva units at large Eastern utility

ALLIS-CHALMERS

Pioneers in Power and Electrical Equipment—Builders of the World's Widest Range of Major Industrial Equipment!

NOW-
LIFE-SPAN
POLES
Eliminate the Added Ground-Line Treatment

Life Span

A Dow Chemical Company's powerline at Midland, Michigan. Western Red Cedar Class 3-50' poles installed in 1942. Full length non-pressure treated with pentachlorophenol only, by Consolidated Treating Company. Groundline of all poles is perfectly sound

An old problem solved a modern way

After years of intensive research, Life-Span Chemists have perfected a new, two-way treatment that does the complete pole protection job. Result: Added years of service with *still lower* maintenance costs.

The new Life-Span treatment involves two steps, each making its scientific contribution to better, low-cost poles. First, the pole is completely immersed in a hot, high-toxic, pentachlorophenol solution. This operation heat-sterilizes the sapwood, and expands the air within the wood cells. The pole is next subjected to the second step in the process . . . a sudden immersion in a cold pentachlorophenol solution. This contracts the air in the wood cells, and insures the required retention of the preservative.

The half-inch incised ground line area results in twice the preservative concentration or retention and insures double protection to this vulnerable portion of the pole.

Life-Span poles are favored by linemen because they are clean, non-conductive, easy and safe to handle. Farmers need have *no* fear for their animals; they're safe with Life-Span! For a better buy in poles, better buy Life-Span Poles. Now available in Western Red Cedar, Douglas Fir, Western Larch, and Lodgepole Pine.

Sold only by the following:

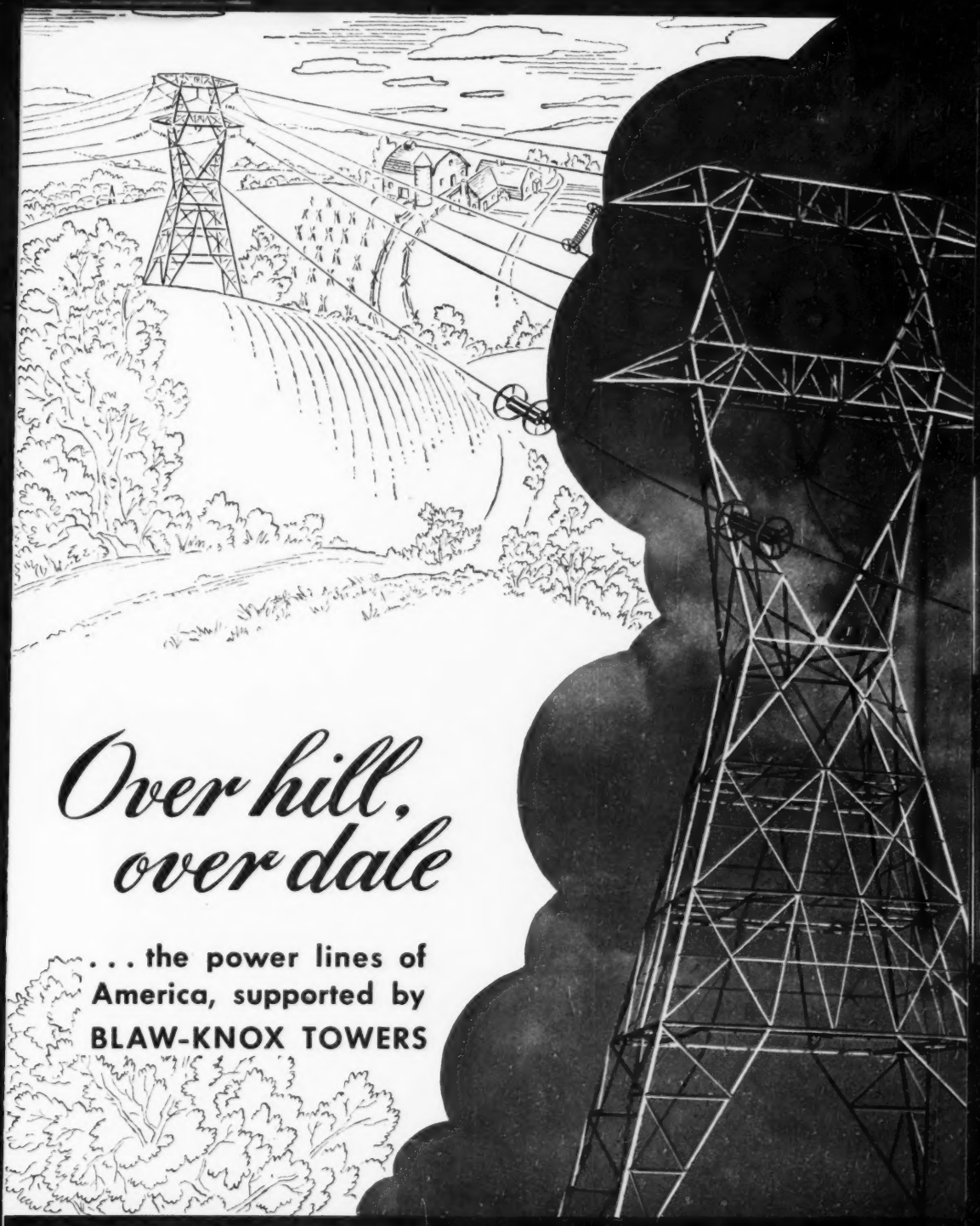
NAUGLE POLE & TIE CORP.
Chicago, Illinois

PAGE & HILL INC.
Minneapolis, Minnesota
50 Church Street, New York, N. Y.

B. J. CARNEY & CO.
Spokane—Minneapolis

SCHAEFER-HITCHCOCK CO.
Sandpoint, Idaho
Suppliers for Joslyn Mfg. & Supply Co.

CONSOLIDATED TREATING CO.
Minneapolis **Minnesota**



Over hill, over dale

. . . the power lines of America, supported by

BLAW-KNOX TOWERS

BLAW-KNOX TRANSMISSION TOWERS

BLAW-KNOX DIVISION OF BLAW-KNOX COMPANY • 2013 FARMERS BANK BLDG., PITTSBURGH, PA.

NEW YORK CHICAGO PHILADELPHIA BIRMINGHAM WASHINGTON

YOU CAN BE SURE.. IF IT'S
Westinghouse

Johnny's "Short Cut" takes 3,000 kilowatts now!

. . . just an old field on the edge of town. A few years ago, Johnny saved ten minutes getting home. Now his favorite short cut proudly displays 400 new homes.

Are you prepared to economically handle this new load?

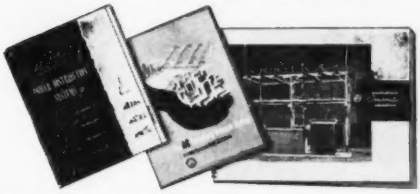
Sure, it's difficult to predict such future loads . . . BUT you can *plan* for them! For the first time in a good many years, you have a *real* opportunity to rebuild and simplify your system.

This doesn't mean you have to scrap your present equipment. It does mean that replacements and extensions should be made with a *modern system plan* in mind. Its flexibility meets *future* requirements. System planning actually means *less equipment* . . . but *better co-ordinated equipment.*

How can Westinghouse help you in this problem?

We can assist you in your *system planning.* Our engineers have worked with utility engineers throughout the country. Together, we have solved power distribution problems of all kinds and we have learned to *plan* systems and co-ordinate *all* distribution apparatus.

Our complete facilities . . . engineers, calculating boards, service organization . . . are all available to help *you.* May we be of help in your *system planning?* Call your nearest Westinghouse office or write Westinghouse Electric Corp., P. O. Box 868, Pittsburgh 30, Pa. J-97138



YOUR "Know-How" Put to Work

One of the many ways in which Westinghouse can help you in your problem is to crystallize and formulate the best thinking on *system planning.* Here are three outstanding books to help you:

"Electric Utility Power Distribution Systems", B-3905—explains and classifies typical systems for *all* types of areas.

"Co-ordinated Substations", B-4061—presents a complete standardized line of substations, designed and manufactured to answer any *system* requirement.

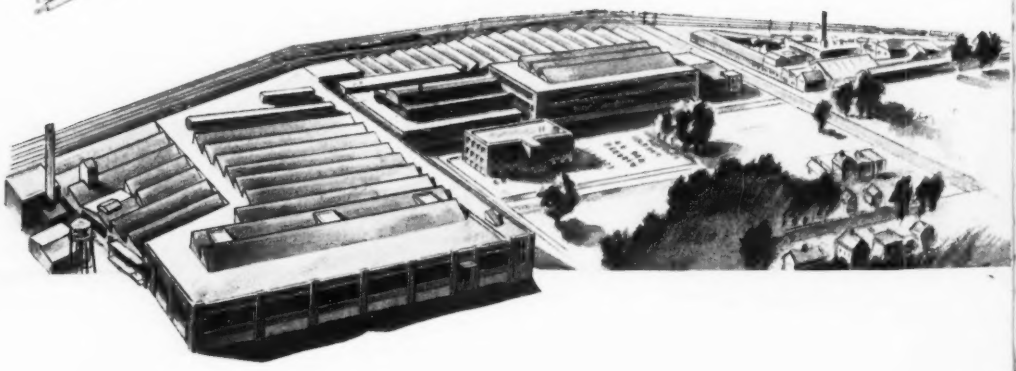
"A-C Secondary Network Systems", B-4002—is the complete story of a system that has saved the utilities at least $175,000,000.

ASK FOR A PRESENTATION OF THIS VALUABLE INFORMATION

Westinghouse

SYSTEM PLANNING SERVICE

What's behind



a Name . . . ?

There may be little behind a name . . .
Then again there can be much.

Founded as an independent company in 1936, Rome Cable is young . . . yet the *men who are Rome Cable* measure their wire and cable experience in decades of close association with the art of power transmission. Their experience . . . plus a high regard for quality . . . gives to Rome Cable products a value transcending normally accepted standards.

Progressively broadening its service to the electrical industry, Rome Cable has never lost sight of its avowed purpose . . . *to produce wires and cables of the best possible quality and render dependable customer service.*

You can rely upon those names beginning with the prefix "Ro" or the word "Rome." Behind them is an unbroken record of unexcelled performance and serviceability.

Rome 60
★
RoZone
★
RoFlex
★
RoLene
★
RoMarine
★
RoPrene
★
Rome
SYNTHINOL
★

REMEMBER THESE NAMES
FOR DEPENDABLE QUALITY

FROM BAR TO FINISHED WIRE

ROME CABLE
CORPORATION
ROME • NEW YORK

Maximum Service Life Transmission and Distribution Line Poles

BELL poles, subjected to preservative processing through Bell plants, will bring to you assurance of more-than-average service years for your lines. Continuing research, modern pole processing plant facilities and expert supervision (with a background of 60 years production experience) combine to provide poles of finest appearance and time-approved quality — a quality consistently maintained by close and rigid step-by-step control from the tree stump through the preservative processing to the finished product. Let the Bell "know-how" furnish the poles for your line construction needs.

High Altitude Western Red Cedar Poles (*) — With Guaranteed Half-Inch or Full Sapwood Butt Treatment (1) only — "Long-Life" Processed (2) full length.

Mountain Douglas Fir Poles (*) — With Guaranteed Half-Inch or Full Sapwood Butt Treatment (1) only — "Long-Life" Processed (2) full length — "Life-Time" Processed (3) full length — Pressure-Treated full length.

Western Larch/Tamarack (*) — With Guaranteed Half-Inch or Full Sapwood Butt Treatment (1) only — "Long-Life" Processed (2) full length — "Life-Time" Processed (3) full length — Pressure-Treated full length.

1—Incised Ground Line by the Machine Fibre-Spreading Method — No crushing, breaking or loosening of sapwood — sustained original pole strength guaranteed.

2—Full length Machine Shaved ("turned" as though put through a lathe) for sapwood reduction before full length treating.

3—Full Length Machine Shaved and Full Length Incised by Fibre-Spreading Process before full length treating.

*—A.W.P.A. Grade 1 Creosote Oil and 5% by weight Pentachlorophenol used as standard Preservatives — only the most modern processing facilities are employed.

● Removing poles from a full length treating tank — the completed "Long-Life" and "Life-Time" treating process.

BELL 1949 LBR. & POLE CO.

BELL LUMBER & POLE CO.

Minneapolis, Minn.

PENTA

(Santophen 20)

CHLOROPHENOL preservative

Lineman prefer Penta-clean treatment

CLEAN, THOROUGH PROTECTION all along the line

The Monsanto Penta treatment is the dependable way to give wood long-lasting protection against rot, termites and other wood-boring insects. Penta solutions penetrate thoroughly — leave poles CLEAN and dry . . . This means better workability for linemen, improved appearance.

Monsanto's Penta should be used to extend the service life of poles — to protect crossarms and braces by preventing dangerous decay resulting from moisture accumulations around bolt holes . . . This is your assurance of greater safety for linemen, more protection for valuable line materials.

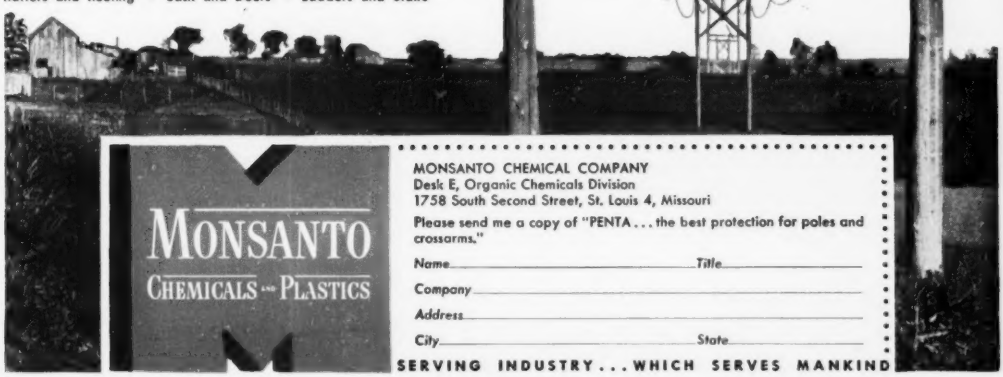
If you would like to learn more about the advantages of treating with Monsanto's Penta, send today for a copy of the booklet, "PENTA . . . the best protection for poles and crossarms." MONSANTO CHEMICAL COMPANY, Desk E, Organic Chemicals Division, 1758 South Second Street, St. Louis 4, Missouri.

Santophen: Reg. U. S. Pat. Off.

WHERE PENTA MAKES WOOD LAST LONGER

Poles • Crossarms • Braces • Platforms and Decking • Loading Docks • Catwalks and Railings • Tool and Machinery Sheds Trestles and Bridges • Guardrails • Flooring • Sills, Plates, Joists Rafters and Roofing • Sash and Doors • Ladders and Stairs

Transmission lines in Kansas . . . These Western red cedar poles were full-length treated with Monsanto's Penta.



MONSANTO CHEMICALS AND PLASTICS

MONSANTO CHEMICAL COMPANY
Desk E, Organic Chemicals Division
1758 South Second Street, St. Louis 4, Missouri

Please send me a copy of "PENTA . . . the best protection for poles and crossarms."

Name _____ Title _____

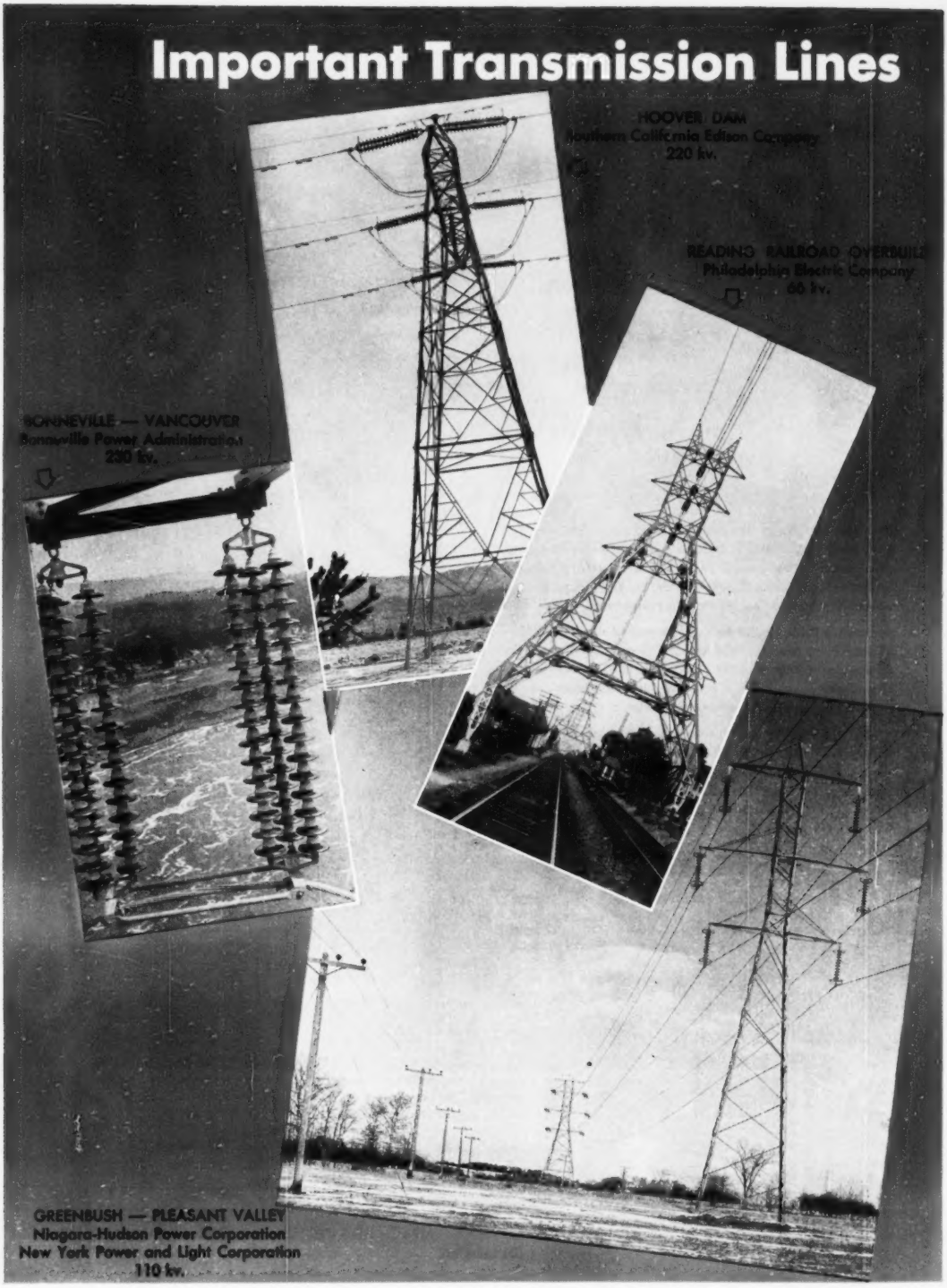
Company _____

Address _____

City _____ State _____

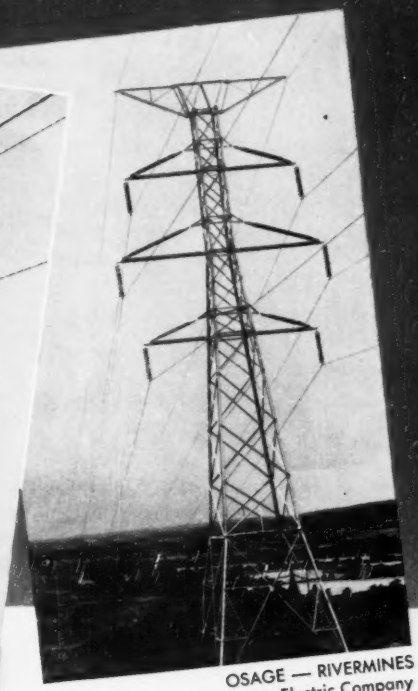
SERVING INDUSTRY . . . WHICH SERVES MANKIND

Important Transmission Lines



Use BTC Forged Hi-Line Hardware

NEW HOPE — PLYMOUTH MEETING
Philadelphia Electric Company
220 kv.



OSAGE — RIVERMINES
Union Electric Company
138 kv.

Hardware for important transmission lines should have a record of dependable service as evidence of good engineering and materials.

BTC drop forged steel Hi-Line clamps and fittings have proved their superior qualities in actual use through years of service on these and many other outstanding transmission lines. Over rugged terrain, river crossings, high altitudes, and in all kinds of weather, BTC forged hardware is still giving entirely satisfactory service.

For proper design and long-run economy in maintenance, specify BTC drop forged steel Hi-Line hardware for your transmission line.

6200 Series Clamp

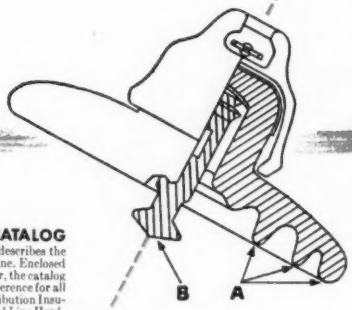
Sold only through your insulator manufacturer

THE BREWER-TITCHENER CORPORATION
CORTLAND, N. Y.

THOMAS details make a big difference in insulator life

No one part of an insulator is more important than another. Long life is dependent upon the proper balance of all electrical and mechanical characteristics. This attention to detail and manufacturing "know-how" does not come overnight. Thomas has been manufacturing porcelain insulation for 76 years and is still seeking better and improved methods of serving the electric utility industry . . . is still refining its products for more efficient insulation of transmission and distribution lines.

To you as a user of insulators, these refinements mean extra years of trouble-free performance. Specify Thomas Porcelain for all your insulator requirements . . . There are no "weak links" in Thomas Insulators.



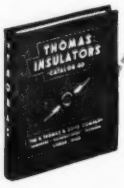
This cutaway view is a Thomas Ten-Inch Suspension-Strain Insulator, 15,000 pounds M. & E. rating. Illustrated are two of the many plus characteristics evident in all Thomas made porcelain insulators.

A—Corrugations are rugged and thick . . . tough enough to withstand malicious or accidental breakage. Deep and rounded, they provide maximum leakage surface. Rolled edges prevent chipping and breakage. Thomas design is right . . . Thomas porcelain is tough.

B—Forged steel studs are set and held fast by high grade cement. Perfect alignment is assured, for all parts are jig assembled . . . clamped tight until cement sets. Complete interchangeability, uniform quality and long life are guaranteed with Thomas Insulators.

THIS FREE CATALOG

. . . illustrates and describes the complete Thomas line. Enclosed in a loose-leaf binder, the catalog provides a ready reference for all Transmission-Distribution Insulators and Associated Line Hardware. New insertions as issued are sent to all catalog holders.

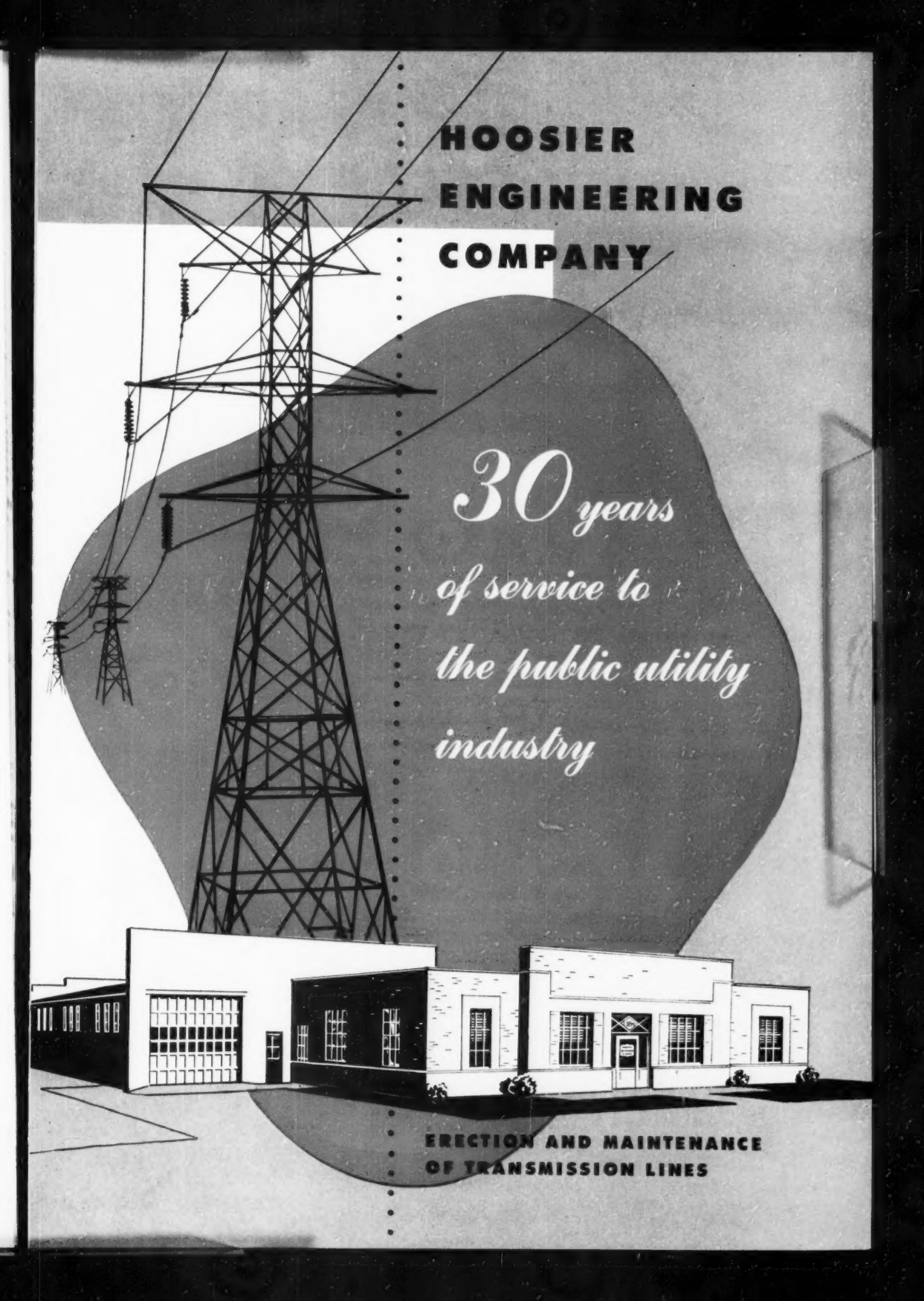


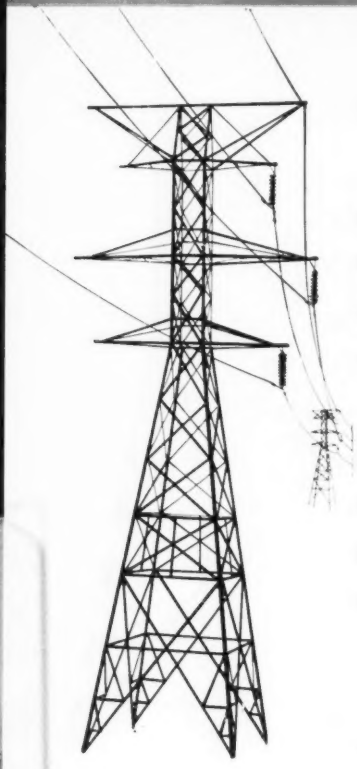
The R. Thomas and Sons Co.

LISBON, OHIO

NEW YORK CHICAGO

AGENTS IN PRINCIPAL CITIES


HOOSIER
ENGINEERING
COMPANY
30 years
of service to
the public utility
industry
ERECTION AND MAINTENANCE
OF TRANSMISSION LINES



HOOSIER *Experience* SERVES TO.

For more than a quarter of a century, Hoosier engineers, trained men, and special equipment have helped in the erection and maintenance of the vast network of transmission lines in this country and Canada.

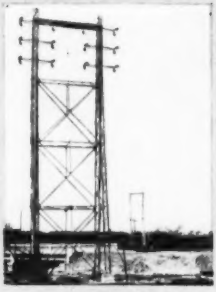
We are justifiably proud of our part in building an electric power industry capable of producing more power than the rest of the world combined. Proud, too, that among the names of those companies served by Hoosier can be found nearly every important utility and many large industries.

Strategically located throughout the country, Hoosier

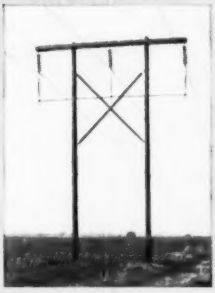
Typical HOOSIER *installation*

Ohio

Montana

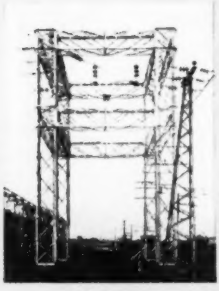


Michigan



Nebraska

Virginia



New York

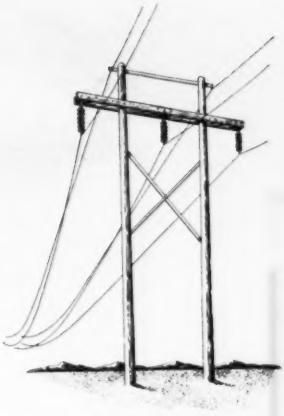
Illinois

Iowa

MEET AN EVER-INCREASING DEMAND FOR POWER

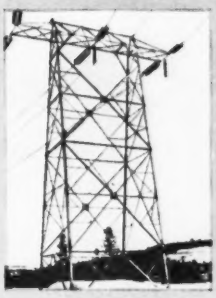
engineers are well acquainted with every type of terrain . . . experienced in handling the most difficult construction. As a result, HOOSIER-built jobs continue to withstand the most severe tests of time and elements . . . continue year after year, to give maximum service with minimum interruption.

Hoosier service is ready today, as always, to furnish experienced and highly trained men . . . specialists possessing wide and varied experience in the "know-how" of erection and maintenance of transmission lines . . . to efficiently and economically assist you in building and maintaining adequate service.



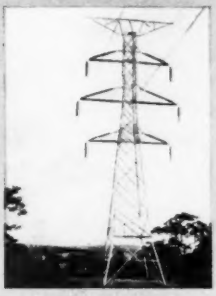
. . . in the United States and Canada

Wisconsin



Canada

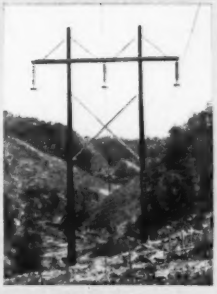
Florida



Missouri

North Carolina

West Virginia

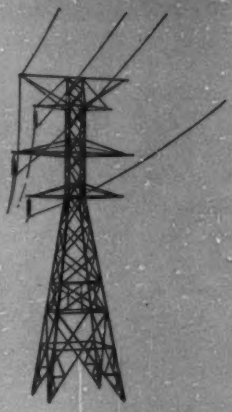


Kentucky

New Jersey

Partial list of companies served by Hoosier

Aluminum Company of America
Arkansas Power & Light Company
Appalachian Electric Power Company
Indiana & Michigan Electric Company
Indiana Service Corporation
Atlantic City Electric Company
Public Service Company of Northern Illinois
Northern Indiana Public Service Company
Montana Power Company
Ohio Power Company
Mississippi River Power Company
Montana Dakota Utilities
Public Service Company of New Hampshire
Carolina Power & Light Company
Pennsylvania Electric Company
Detroit Edison Company
Union Carbide & Carbon Company
Ohio Public Service Company
Platte Valley Public Power & Irrigation District
Wheeling Electric Company
Iowa Southern Utilities Company
Columbus & Southern Ohio Electric Company
Illinois Northern Utilities Company
Dayton Power & Light Company
Edison Sault Electric Company
Kentucky Utilities Company
Kentucky & West Virginia Power Company



ERECTION AND MAINTENANCE OF TRANSMISSION LINES

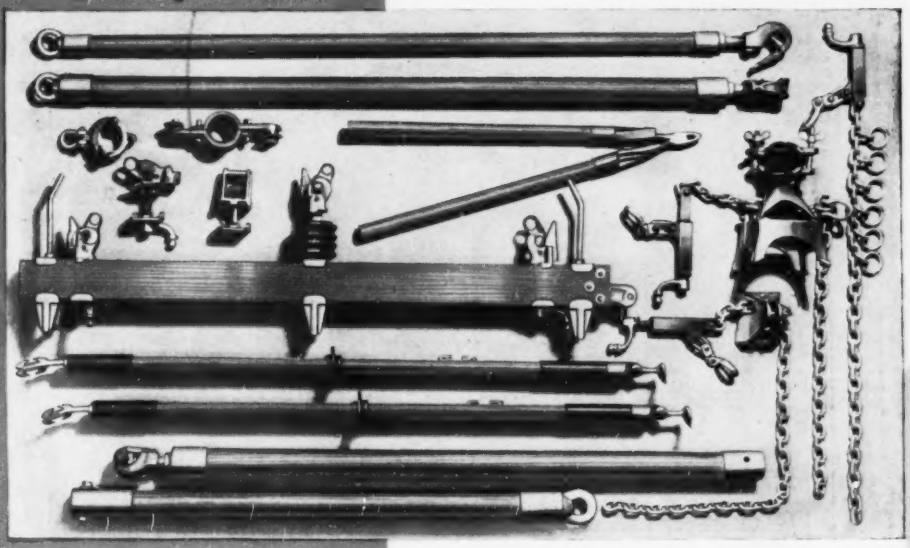
NEW YORK • 1384 HOLLY AVE., COLUMBUS, OHIO • CHICAGO

HOOSIER ENGINEERING CO.

PRINTED IN U.S.A.

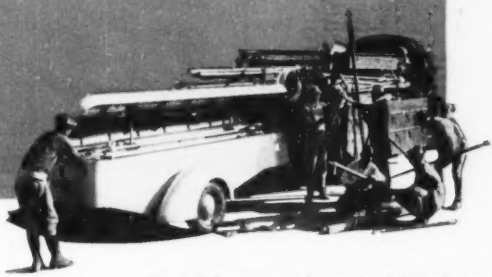
CONGRATULATIONS, ELECTRICAL WORLD. ON YOUR 75TH ANNIVERSARY

For *Safer* Maintenance



Illustrating the Rural Line Set, Catalog # 18-3

# of Energized Lines



Always aware of the importance of keeping the meters turning and mindful of the need for safety in working energized lines, the James R. Kearney Corporation designed the Hi-Line Tool Sets.

Wood units are tested to 75,000 volts per foot for a period of five minutes and all units are carefully inspected to insure maximum safety to linemen.

The Kearney Hi-Line Trailer saves hours of time on the job because it keeps tools handy and always in good condition. The heating unit built in provides additional safety by keeping tools dry.

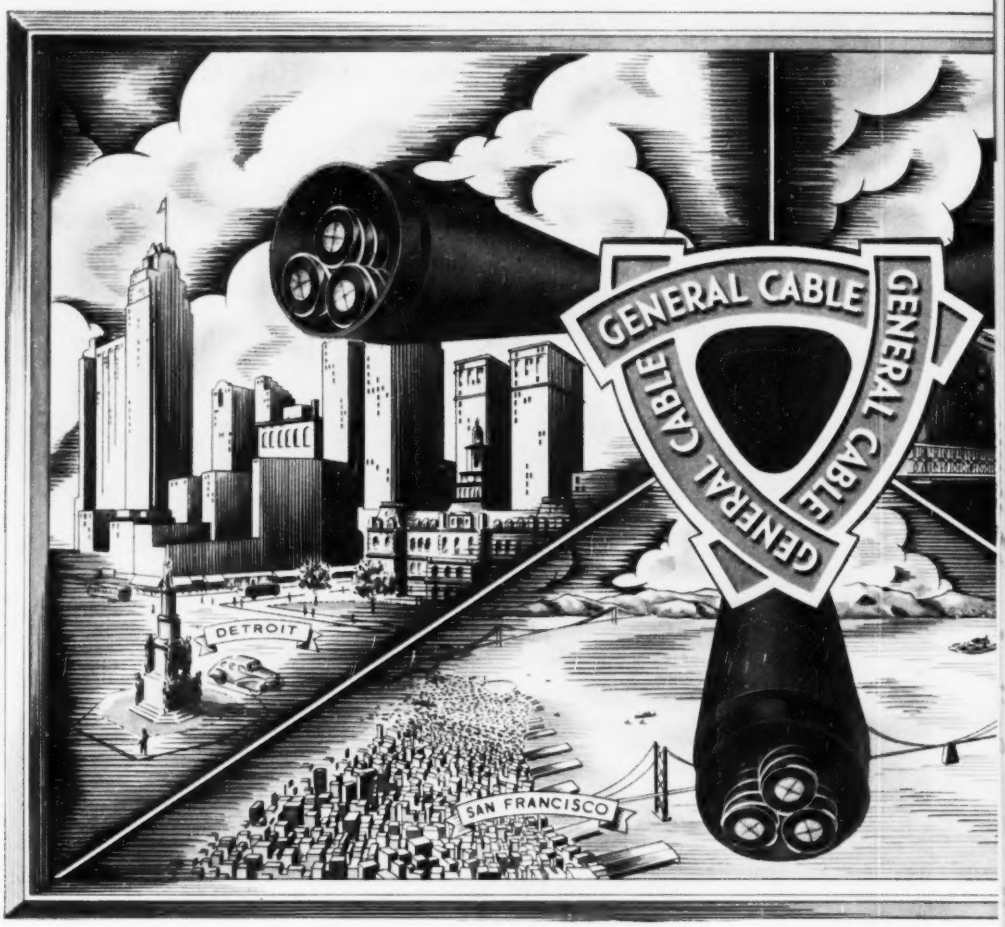
JAMES R. KEARNEY CORPORATION 4224-42 Clayton Avenue • Saint Louis 10, Missouri

Canadian Plant: Guelph, Ontario

-133

Always Specify JAMES R. KEARNEY CORPORATION ST. LOUIS, MO. *for the Job...*

Better Construction – *SAFER* Maintenance



LOOK TO GENERAL CABLE

1st for Engineering

to supply High Pressure Gas Filled Pipe Type Cable for experimental field installation.

to supply High Pressure Gas Filled Pipe Type Cable for a commercial installation.

installation of any Pipe Type Cable under paved city streets.

to ship Pipe Type Cable without a temporary lead sheath.

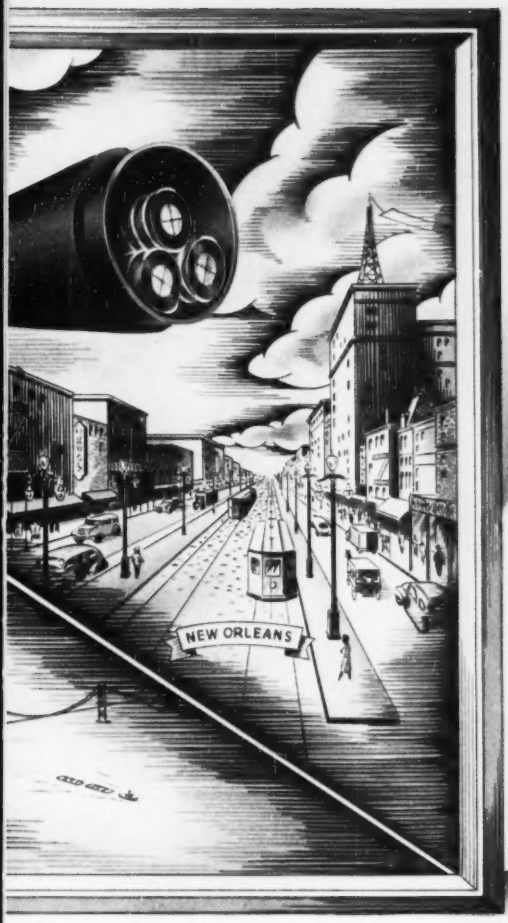
to use ultra high viscosity oil for mass impregnation of High Pressure Gas Filled Pipe Type Cable.

to supply lengths of Pipe Type Cable half-mile and longer suitable for pulling without special full external armor.

to develop Compack Segmental Conductors now widely used in pipe type systems.

installation of High Pressure Oil Filled Pipe Type Cable without semi-stop joints or man-holes.

cable manufacturer to use extruded asphalt mastic type of corrosion protective covering on its steel Pipe Type Cable installation.



44% SUPPLIED BY GENERAL CABLE

NOW 110 CIRCUIT MILES OF PIPE TYPE CABLE FOR 100 Kv OR OVER

May 1, 1949.—For 100,000 volts and higher underground power transmission, the high pressure Pipe Type Cable Systems, gas-filled or oil-filled, dominate the scene. At this writing, the lines in service comprise a total of over 110 circuit miles.

Advance—

ON PIPE TYPE CABLE

to develop and use the effective strip grip for controlling "thrust" at stuffing box glands of semi-stop joints.

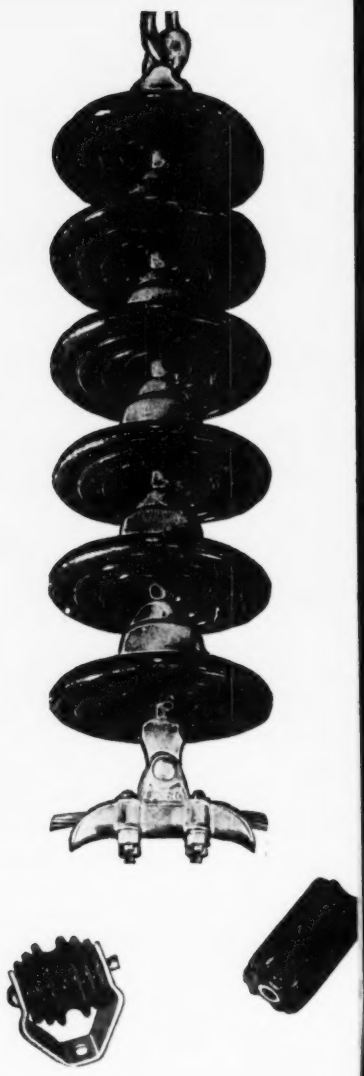
cable manufacturer to share in the publishing of Test and Design Data on Thermal Charac teristics of Pipe Type Cable Systems based upon field tests.

to install a Switching Surge Generator for cable tests and to publish resulting data on pipe type cable.

GENERAL CABLE
CORPORATION

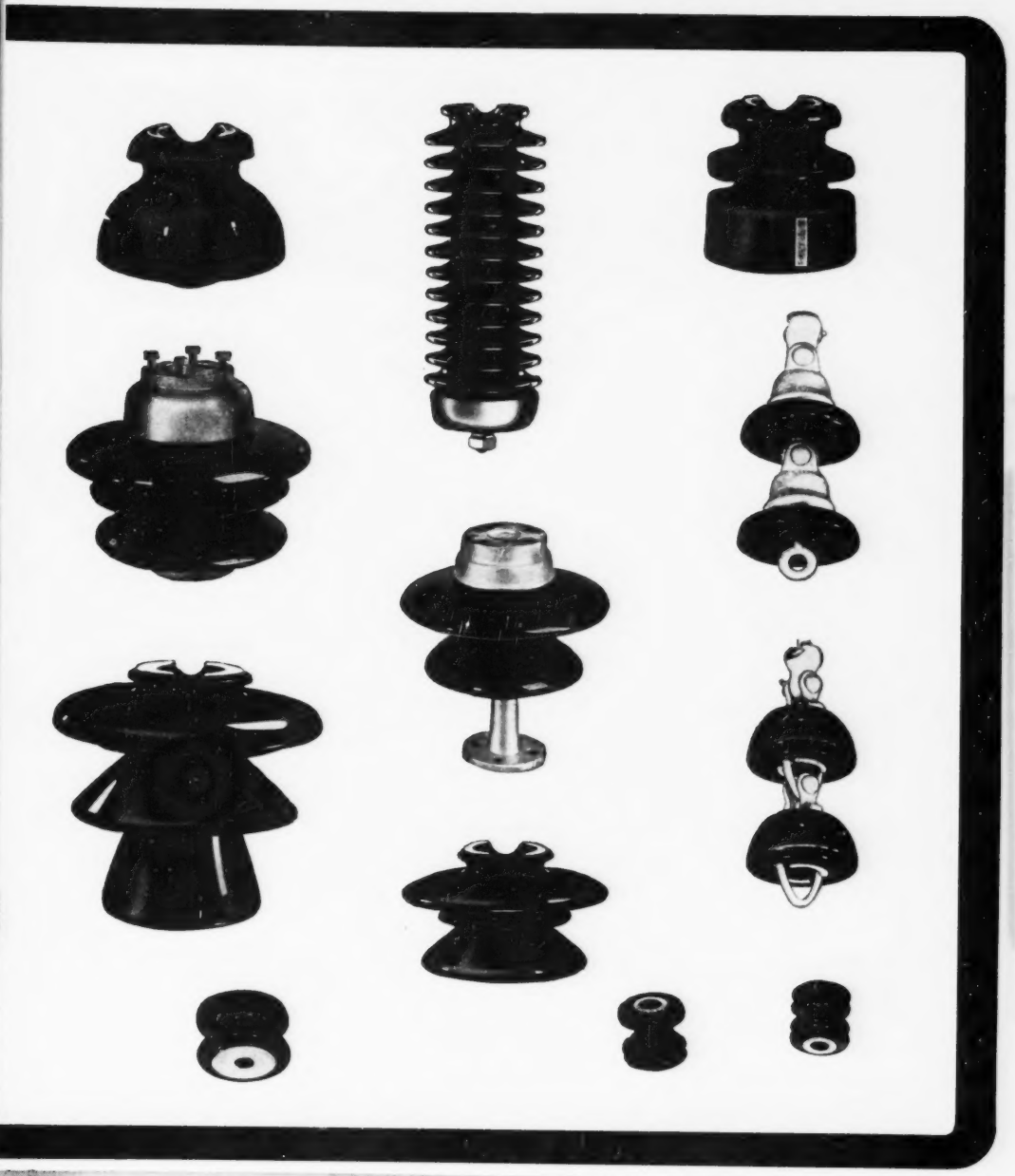
SALES OFFICES IN PRINCIPAL CITIES

A Complete Line OF Porcelain Insulators



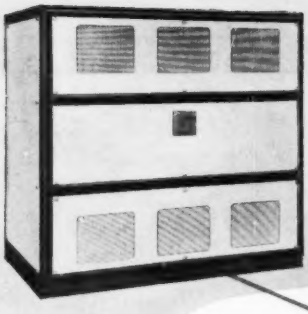
J-D

JEFFERY -



DEWITT INSULATOR CORP.

KENOVA, WEST VIRGINIA, U.S.A.

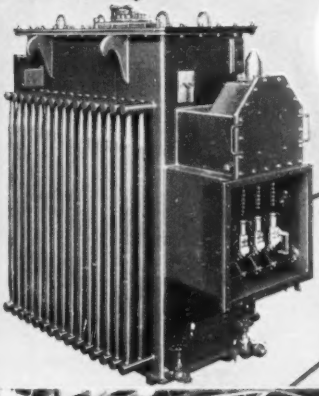


DRY TYPE
Natural and Forced Air Cooled

1000 KVA, 3 phase,
80°C. rise
Class B Insulation
4160Y—480 Δ volts

NETWORK
Submersible and Vault type

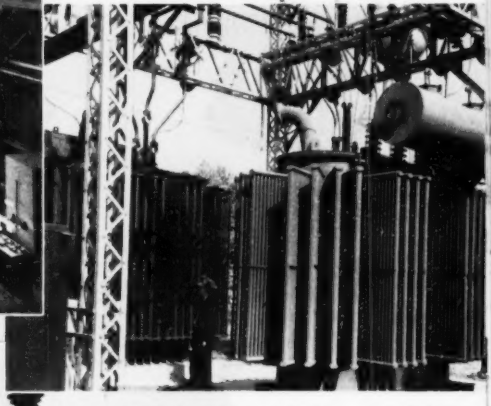
500 KVA,
3 phase,
60 cycles
7200/12,470Y-
208Y/120

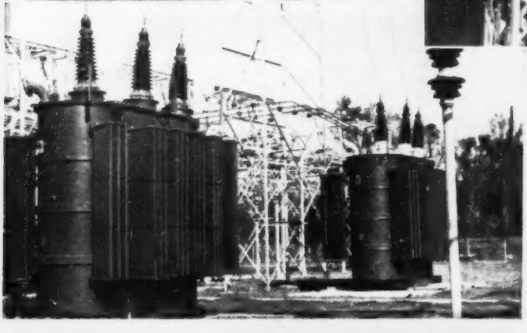


Pennsylvania TRANSFORMERS

The TRADE

View of Main Assembly floor at Pennsylvania's modern plant in Canonsburg, Pennsylvania.



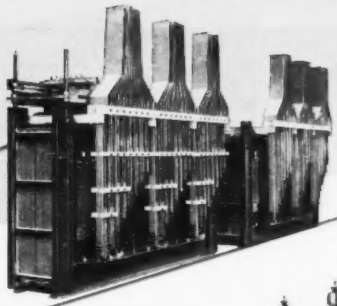


ONE 5000 KVA and ONE 7500 KVA, 3 phase, 60 cycles, OA. 33,000 Δ — 2400/4160Y volts.

TWO 7500 KVA Pennsylvania Transformers, 3 phase, 60 cycles, OA. 115,000Δ—13,800Y/8000 volts.

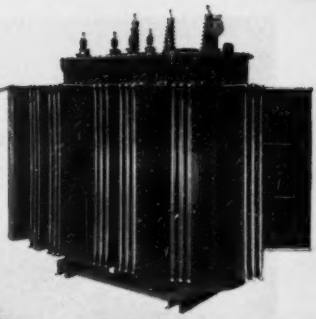
FURNACE
For operating Electric Arc Furnaces as large as 75 tons.

2—10,000 KVA, 3 phase, 60 cycles, OIWC.



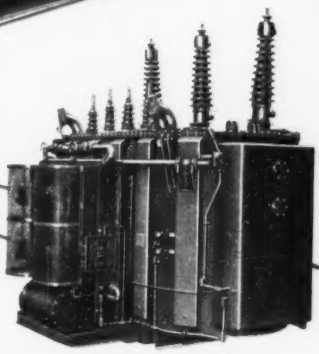
POWER
667 KVA to 50,000 KVA
Up to 230,000 volts.

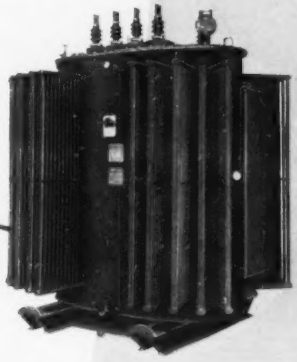
Detachable Radiators
15,000 KVA, 3 phase, 69,400Y— 13800 Δ volts



LARGE POWER
Forced-Oil Cooled

30,000 KVA, 3 phase, 132,000— 25,000 volts





STANDARD PARTS POWER
Up to 10,000 KVA
Up to 34.5 KV

3750 KVA, 3 phase, OA, 12,000 Δ — 4160Y volts

MARK that represents

a distinguished product to the electrical world

Sound management, thorough knowledge of the product, and good workmanship is earning Pennsylvania Transformer Company an honored place in the Electrical World. Modern equipment and over ½ million square feet of efficiently arranged floor space enables Pennsylvania's 1100 men and women to concentrate on building good, reliable transformers. A special Planning Department, devoting all of its time to research and development work, promotes improvements such as those incorporated into Pennsylvania's Pole Star and Standard Parts Power Transformers.

TOMORROW, as TODAY, the Pennsylvania trade mark will continue to represent the finest in transformers.

DISTRIBUTION
3 KVA to 500 KVA
Up to 66,000 volts.

500 KVA, single phase, 60 cycles, OA 14,400—240x480 volts

The POLE STAR

25 KVA and below 14,400 volts and below, conforming to E.E.I.-NEMA Standards

Pennsylvania
TRANSFORMER COMPANY
PITTSBURGH 12, PENNSYLVANIA

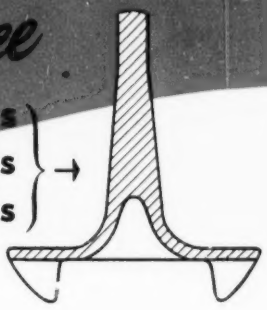
We invite you to write for Pole Star Catalog No. 349, and Pennsylvania Standard Parts Power Transformer Booklet No. 1492.

Pennsylvania's complete line of transformers includes: Askarel Transformers, Unit Substation Transformers, Portable Unit Substation Transformers, and Pipe Welding Transformers.

HUBBARD FORGED STEEL CORNER PINS

One Piece

...no seams
...no joints
...no welds



Hubbard Drop Forged Corner Pins are made from a single piece of steel, forged to a broad base which completely covers the top of the arm. There are no seams, joints or pockets to retain moisture and hasten corrosion.

Due to the one piece construction, maximum strength is retained for the weight of metal used, and radio interference is minimized. Structural strength is also enhanced by the method of attachment, as the strap illustrated binds the wood fibres of the arm in such a way as to prevent splitting.

Hubbard and Company was the first to place this style pin on the market and it has been a popular choice for over twenty-two years. Furnished also with carriage bolts and a separate bottom strap to meet R.E.A. specifications.

HUBBARD AND COMPANY

PITTSBURGH
CHICAGO

OAKLAND
CALIFORNIA

AMERTRAN POWER TRANSFORMERS

...a half century of concentrated experience
AMERTRAN POWER TRANSFORMER
3000 KVA, 60 cycle, 3 phase
13,800 volts delta primary
2400 delta/4160Y with neutral out secondary
OISC

A "jack-of-all-trades" has his points. Yet, on any job he may undertake, he is not likely to get quite the results that one who concentrates in that same field can accomplish. It means something, therefore, that AmerTran has given its undivided attention for almost a half-century to transformers and closely related products. During that time we have produced the best transformers that concentrated experience can devise.

Who says so?

Our customers say so—and the evidence is in their repeat orders. You, too, will find it pays to specify AmerTran in your transformer requirements.

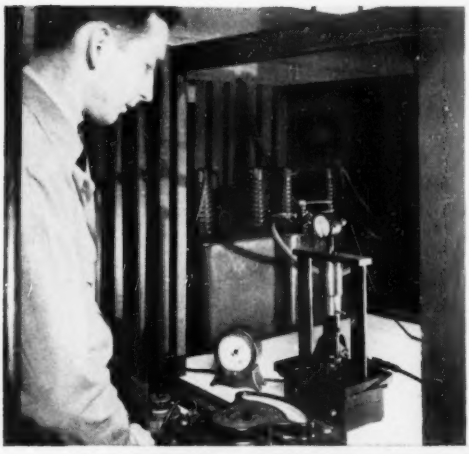
AMERTRAN

MANUFACTURING SINCE 1901 AT NEWARK N. J.

AMERICAN TRANSFORMER CO.
178 Emmet St., Newark 5, N. J.

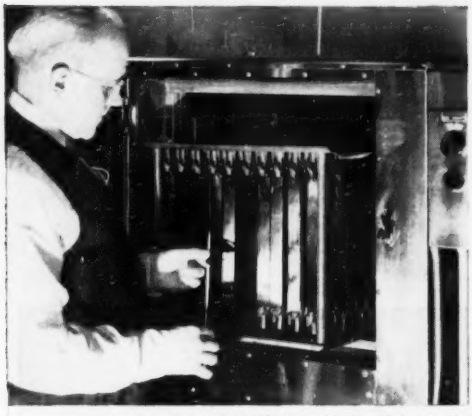
If you need

but are cramped for space



Samples from each lot are tested for dielectric strength and are required to withstand 1000 volts per mil at room temperature.

Hot oil test. Varnished cambric is subjected to a severe heating test—hot petroleum at 150°C. for a period of 15 minutes. After cooling the varnished coating must not be softer nor more tacky than before immersion.



Precisely controlled ovens subject varnished cambric to aging tests far in excess of normal requirements.

The cambric tape is critically examined for gauge, thread count and tearing strength. Tensile strength lengthwise must not be less than 3000 psi.

more power

—use American Varnished Cambric Cables

Maximum power, minimum size, lower costs and ease of installation—these are the chief advantages of U·S·S American Varnished Cambric Cables.

● How to get the most power from the smallest cable is a problem continually being faced by electrical engineers. The improved varnished cambric wires and cables offer a happy solution in many cases.

The varnished cambric used by American Steel & Wire Company is being recommended for operating temperatures up to 85°C. (185°F.). In this respect it is notably superior to rubber . . . permits greater current carrying capacity. It also has higher dielectric strength which results in cables of smaller outside diameter. In multiple conductor cables, part of the insulation may be applied in the form of a belt, thus reducing outside diameter still further. These features permit varnished cambric cables to carry substantially more power for their size than rubber insulated cables.

The fact that oil and grease do not damage varnished cambric insulation makes it widely used for motor and generator leads, transformers, regulators and oil circuit breakers. It is particularly desirable for heavy power lines in power plants, factories and mills.

With the protection of a lead sheath, (Type PS Strand Shielding used over 2KV) varnished cambric can be used where continuous exposure to moisture is expected. Combined with asbestos insulation, it can be used for extremely hot locations.

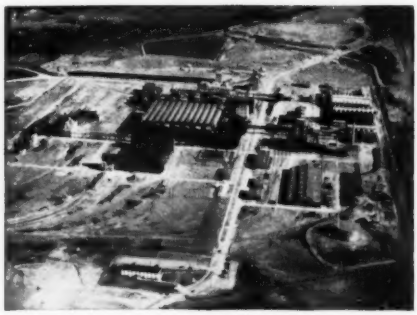
For complete information on the many types of U·S·S American Varnished Cambric Cables, write for our technical booklet.

AMERICAN STEEL & WIRE COMPANY, GENERAL OFFICES: CLEVELAND, OHIO
COLUMBIA STEEL COMPANY, SAN FRANCISCO, PACIFIC COAST DISTRIBUTORS
TENNESSEE COAL, IRON & RAILROAD COMPANY, BIRMINGHAM, SOUTHERN DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

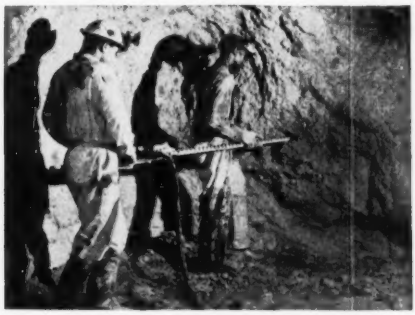
USS **American Varnished Cambric Wire and Cable**

UNITED STATES STEEL

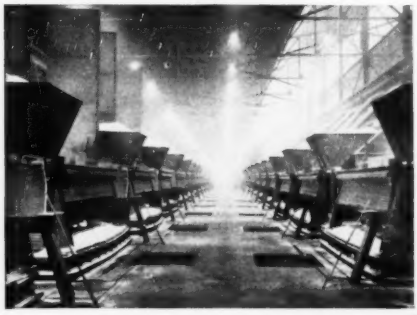
ACSR



Reynolds Listerhill, Ala. plant where ore is converted to alumina.



Mining bauxite (ore) in Arkansas. Reynolds also owns ore in Jamaica and Haiti.



Electrolytic reduction cells in which alumina is broken down into aluminum and oxygen.

REYNOLDS ALUMINUM

REYNOLDS METALS

Pouring aluminum pig at one of four Reynolds reduction plants having a total yearly capacity of over 470,000,000 lbs.

Group of Reynolds wire drawing machines.

and Aluminum Cable

FOR EARLY DELIVERY!

REYNOLDS METALS MAKES FIRST SHIPMENTS ONLY 90 DAYS AFTER ANNOUNCING ENTRY INTO ALUMINUM CABLE FIELD

EVERYONE has talked about the shortage of ACSR—only Reynolds acted quickly to supply your needs.

Reynolds took a realistic approach to your problem—obtained new power supply which would permit the production of additional virgin aluminum. Result—6 million pounds of this metal has now been added to Reynolds monthly capacity, the bulk of which is tagged exclusively for aluminum cable use now and in the future.

Ninety days after Reynolds gave this program "the green light" the first shipment of ACSR was on its way. Yes, Reynolds is in the aluminum cable business—right now! We will welcome your inquiries for early delivery.

COMPANY

Louisville 1, Kentucky

First reel of Reynolds ACSR delivered April 8th.

PINCO Looks Back Proudly

We here at Pinco are proud of the part our company has played in the building of America's vast utility industry. And while our role as a supplier of essential material does not reach back to the early days of the industry's development, we do nevertheless, have a deep feeling of pride and satisfaction in the knowledge that Pinco has pioneered many notable "firsts" in product design improvements during the twenty-eight years of its existence . . . improvements which have increased the strength, ruggedness and over-all efficiency of Pinco units, which in turn have stepped-up "service" life expectancy and cut maintenance costs to a minimum. Today, these same ideas first introduced by Pinco are accepted industry standards . . . proof that Pinco is constantly striving to make a good product *better!*

HERE ARE SOME OF THE PINCO DEVELOPMENTS

NO. 1044

In Low-Voltage Pin-Types . . .

The 1044 is typical of the improved design of all Pinco low-voltage Pin-Types. Heavier, more rugged outer shell, plus the advantage of beaded edges, minimize replacement costs due to handling breakage, gun-shot and stone throwing. Profiled and contoured to stay cleaner longer! Another feature is the larger radius (½") tie wire groove which will accommodate conductors up to and including 3/0 ACSR with rods and a deep snubbing tie wire groove which assures a positive tie.

Service Record—21 Years

In the *Philippines*, Pinco 401's and 1123's in service since 1928.

NO. 75

In High-Voltage Pin-Types . . .

Customer service records show that thousands of Pinco High Voltage Pin-Type Insulators (27 to 70 KV) have been in continuous operation under all conditions since 1921 . . . proof that Pinco's rugged design is the answer to dependable, "RIGHT-on-the-Job" service. In Pinco Multi-Part Units, expert assembly techniques assure the highest degree of efficiency both electrically and mechanically. Drip Points, another design feature of every Pinco Insulator, provide a protected leakage surface under all operating conditions.

Service Record—20 Years

In *Pennsylvania*, Pinco High Voltage Pin-Types in service since 1929.

Suspension Insulators . . . Switch and Bus Insulators . . . Distribution Clamps . . . Distribution Pin-Types and Guy Strains . . . Transmission Line Fittings . . . Tree Insulators . . . Transformer and Circuit Breaker Bushings One Piece and Multi-part High Voltage Pin-Types . . . Suspension and Strain Clamps Indoor Bus Support Porcelain . . . Lightning Arrester Porcelain.

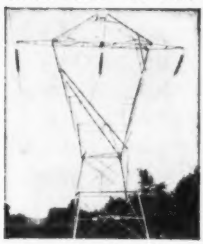
..Looks Forward Confidently

Even now as the nation's electrification program continues in high gear, Pinco production facilities are being expanded to keep pace with the increased demand for its products, aided by modern research and the engineering skill which has helped to establish Pinco as a leader in its field. And as we look to the future, we do so with confidence in our ability to maintain that leadership with the same high standards of quality which have always characterized Pinco products.

The new 1949 PINCO Catalog is a source of information for all those who specify and buy insulators and line hardware . . . the complete story of Pinco and Pinco products. A copy is yours for the asking. . . . Write for it today!

WHICH ESTABLISHED NEW INDUSTRY STANDARDS

Service Record—21 Years



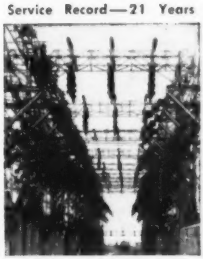
Atlantic Seaboard, Pinco 1060's in service on 132 KV line since 1928.

In Suspension Units . . .

Years ago, caps for suspension insulators had almost straight sides with a sharp, corona-creating projection. Metal bulk was out of proportion to strength. Then Pinco introduced the revolutionary "corset type" cap which provided the most desirable "loading" on the porcelain. It was far stronger, too, even though metal bulk was actually reduced. Another feature is the step-type pin construction which assures "good loading". A protective pad on the Pin End prevents any damage to the porcelain which might result from impact at the pin end. Maximum protection against breakage and greater dielectric strength are assured by extra rugged sections and the proper distribution of porcelain at the critical points.

NO. 1510

Service Record—21 Years



Up-State New York, Pinco 735's in service on 110 KV line since 1928.

In Switch and Bus Units . . .

Down through the years, every Pinco development has been specifically planned to meet increased load requirements both electrically and mechanically. Typical of these is the Pinco 735 Switch and Bus Stacking Unit. With rugged Porcelain and a *larger* second shell, this unit showed far superior flashover performance, greatly reducing the tendency to cascade. In addition, it provided added leakage protection, increased mechanical strength. The thermal characteristics of this and other Pinco Insulators has been greatly improved through the use of Pinco's special resilient compound which provides a cushion for the expansion and contraction of unlike materials assembled together.

NO. 735

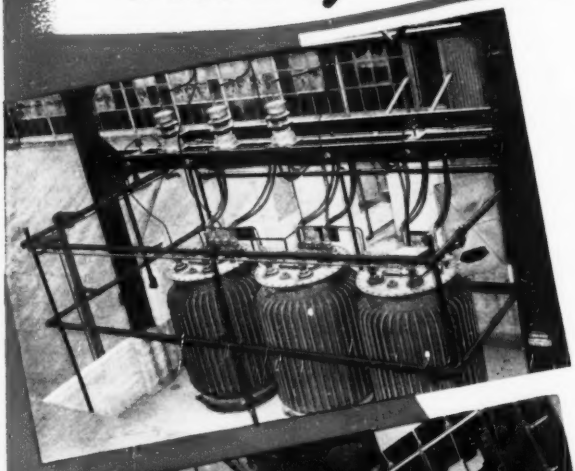
PINCO INSULATORS

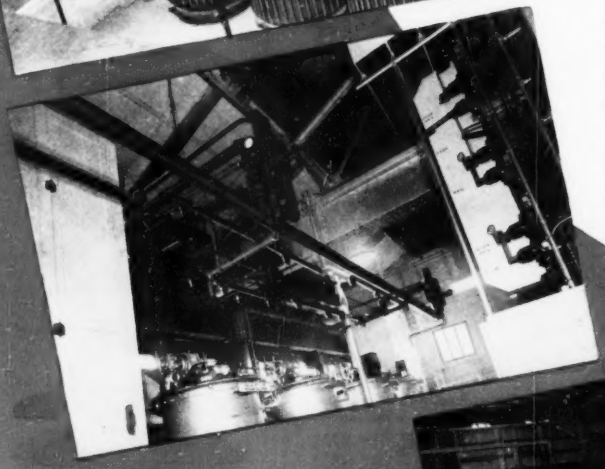
The Porcelain Insulator Corporation

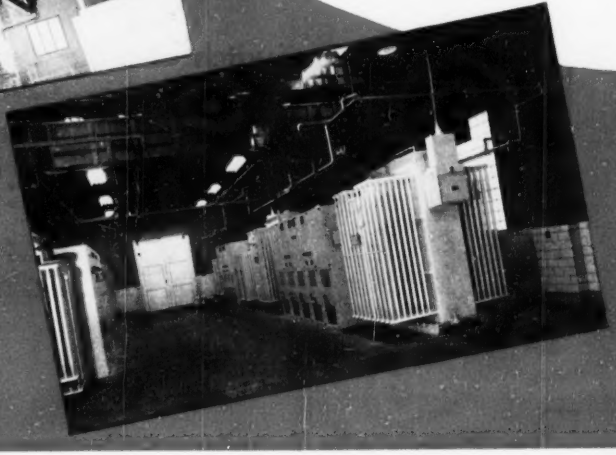
761 Main Street • Lima, N. Y.

Sales Agents: JOSLYN MFG. & SUPPLY CO. *Offices in Principal Cities.*

Analyze Power Failures







HERE'S MUST READING FOR THE ELECTRICAL ENGINEER

You don't have to be an economist to recognize the serious financial losses involved in fire incurred power failures in transformers and associated electrical equipment. They're losses that go far beyond the destruction visible to the human eye. Industrial and commercial out-of-service time for example, often far exceeds actual property damage, yet seldom is it evidenced in fire reports. They're unnecessary losses too . . . for modern *Automatic* FIRE-FOG is now available for the protection of all types of oil filled electrical equipment.

You'll be glad you clipped the coupon!

in terms of dollars and cents

"Automatic" FIRE-FOG
- IT BLANKETS - IT ISOLATES - IT QUENCHES -

DETECT FIRE FAST . . . EXTINGUISH FIRE INSTANTLY

Here's how a FIRE-FOG system works. Detection of fire is automatic . . . operation is instantaneous. From strategically located nozzles, a barrage of fine water spray is directed at the heart of the blaze. Flames are beaten down . . . the fire area cooled, and seconds later, extinguishment is complete with damage confined only to the point of fire origin. Power service may be readily restored and although composed of water, **FIRE-FOG is electrically safe and carries the approval of all leading insurance authorities.**

Industry's unremitting demands have past proved the safe, dependable and economical protection provided by *Automatic* FIRE-FOG. Its acceptance has been widespread as reasoned by the following:

1. **Positive fire extinguishing ability**
2. **Moderate cost of installation**
3. **Minimum cost of maintenance (no expensive chemicals to replace or check)**
4. **Water is the cheapest and most plentiful fire extinguishing agent known.**

Why don't you investigate the safety and financial advantages of *Automatic* FIRE-FOG for your specific fire protection problem? Surveys and estimates are cheerfully furnished without cost or obligation.

"AUTOMATIC" SPRINKLER CORPORATION OF AMERICA
YOUNGSTOWN 1, OHIO

"Automatic" Sprinkler
FIRST IN FIRE PROTECTION

DEVELOPMENT · ENGINEERING · MANUFACTURE · INSTALLATION
OFFICES IN PRINCIPAL CITIES OF NORTH AND SOUTH AMERICA

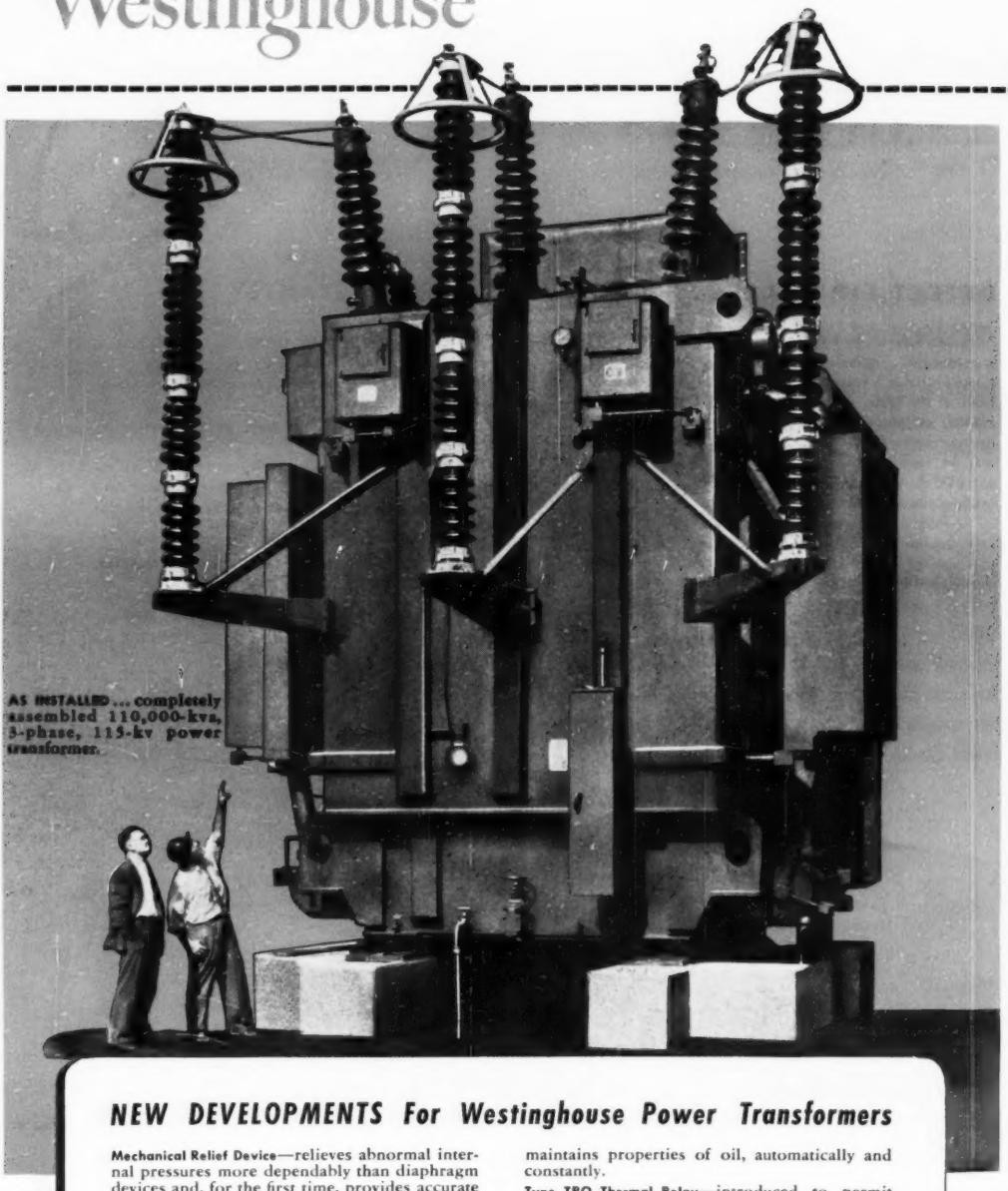
"AUTOMATIC" SPRINKLER CORPORATION OF AMERICA
DEPT. A.—P. O. BOX 360, YOUNGSTOWN 1, OHIO

☐ *Please send me your Bulletin 64, The Design and Application of "Automatic" FIRE-FOG.*
☐ *Please have your representative call for survey and estimate purposes.*

Name _____ Position _____
Company _____ Address _____
City _____ Zone _____ State _____

YOU CAN BE **SURE**.. IF IT'S

Westinghouse



AS INSTALLED ... completely assembled 110,000-kva, 3-phase, 115-kv power transformer.

NEW DEVELOPMENTS For Westinghouse Power Transformers

Mechanical Relief Device—relieves abnormal internal pressures more dependably than diaphragm devices and, for the first time, provides accurate and adjustable tripping characteristics.

Bracket-Mounted Wheels—permitting a 90° change in direction of movement, usually eliminate need for transfer truck.

Thermosiphon Oil Conditioner—when provided, maintains properties of oil, automatically and constantly.

Type TRO Thermal Relay—introduced to permit accurate thermal calibration and control; fully accessible without breaking transformer seal.

Type URS Load Tap Changer—just announced for moderate ratings; less maintenance, more positive in action and more dependable.

Smaller. Lighter

More powerful

The Modern Westinghouse Power Transformer

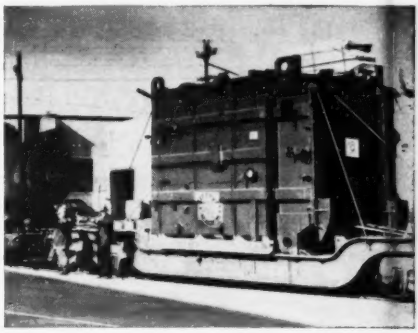
In the face of today's increasing power demands, here's a big stride in the direction of new operating economies.

For power transformers of large ratings, the Westinghouse form-fit, shell-form design makes possible more kva without proportionate increase in size and weight. Even the largest units are shipped assembled because they can be laid on their sides on flatcars or highway trailers. And this construction gets the most out of cooling by forced air and forced oil . . . all for greatest returns on the purchaser's dollar.

Transformers of moderate rating with core-form construction also embody the newest features from the skill and experience of the organization that introduced transformers and has constantly pioneered improvements.

Westinghouse uses the design best suited for the specific job . . . with the proper balance of strengths—mechanical, electrical and thermal—for all operating conditions. Transformers are another Westinghouse product where intensive research and development, combined with careful manufacturing, give you the sureness of best quality. Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pennsylvania.

J-70538



AS SHIPPED . . . same 110,000-kva transformer, filled with oil, shipped in one package, only bushings, coolers and lightning arresters removed.

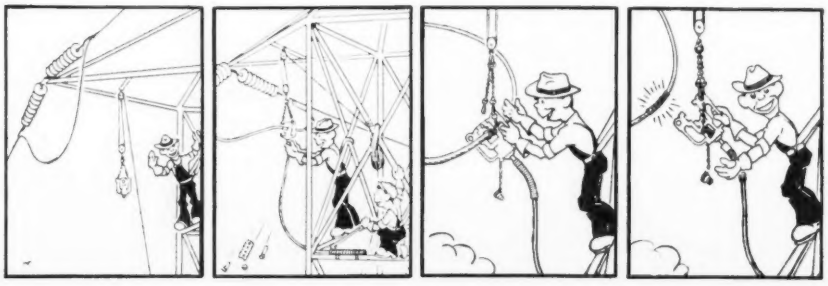
Westinghouse
TRANSFORMERS

T & B METHOD

cuts installation costs with a new line of TOOLS and COMPRESSION for A. C. S. R. setting entirely new *PORTABILITY, PRECISION*

In designing this remarkable new line of A.C.S.R. fittings for transmission and distribution lines, T&B engineers were determined to bring to this heavy duty field for the first time the close tolerances, exact dimensions and superb finishing for which other T&B engineered products have been justly famous. The result we think will create an entire new set of utility specification criteria for this type of fitting. Designed around the tried and proven T&B Method hex compression joint, available in a complete range of standard cable sizes, and installed by unique, portable tools that can be used at any height on any tower, these fittings will give unsurpassed performance, permanence and economy. They have been thoroughly job tested by leading utilities, and are available for demonstration and delivery now.

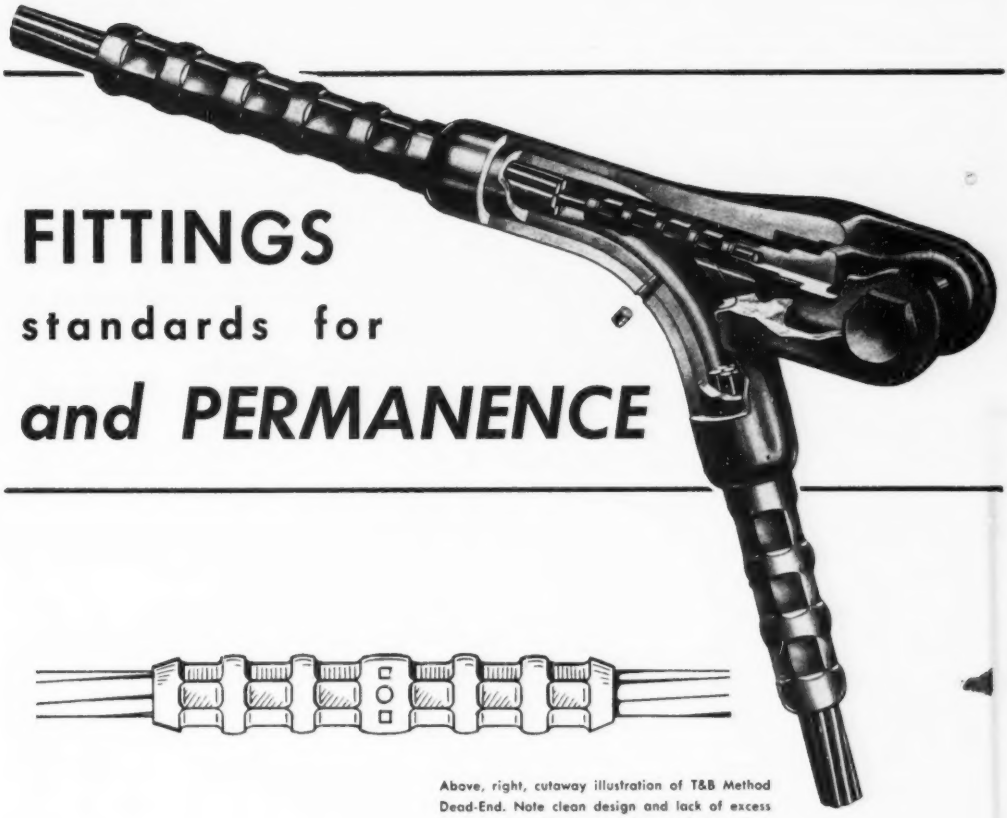
REVOLUTIONARY NEW METHOD OF INSTALLATION permits quick, efficient, safe work on tower. Both pump and installing head are light, portable and are easily run up to desired height. The whole assembly fits into specially designed packs.



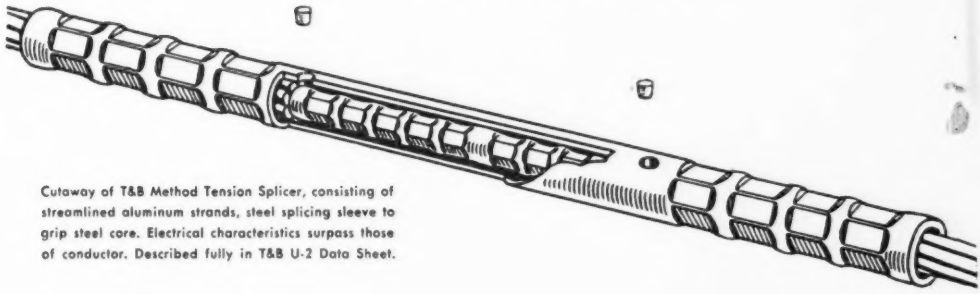
FITTINGS

standards for

and PERMANENCE



Above, right, cutaway illustration of T&B Method Dead-End. Note clean design and lack of excess bulk. At left, T&B Method Jumper Splicer. Both fully described in T&B U-2 Data Sheets which will be sent upon request to qualified applicants.



Cutaway of T&B Method Tension Splicer, consisting of streamlined aluminum strands, steel splicing sleeve to grip steel core. Electrical characteristics surpass those of conductor. Described fully in T&B U-2 Data Sheet.

T&B ENGINEERED

THE THOMAS & BETTS CO.

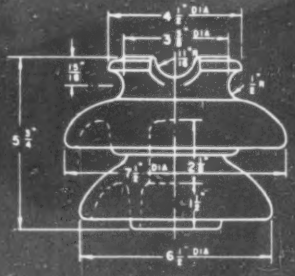
INCORPORATED

ELIZABETH, NEW JERSEY

ADEQUATE WIRING SERVES AND SAVES — THE KEY TO ELECTRICAL LIVING

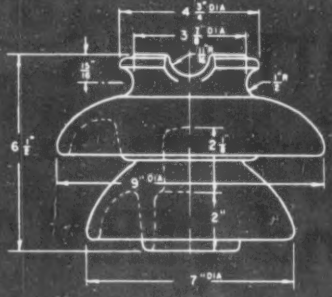
T&B PRODUCTS SOLD ONLY THROUGH THE T&B ELECTRICAL WHOLESALER

The Quality Line



No. 6423
(Supersedes No. 6134)

EACH INSULATOR PACKED IN AN INDIVIDUAL CARTON



No. 6434
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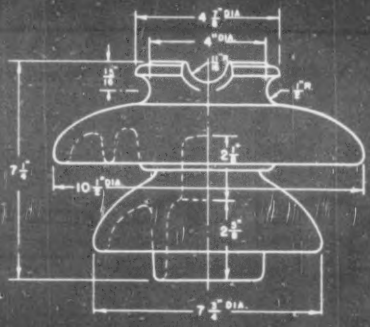

No. 6446
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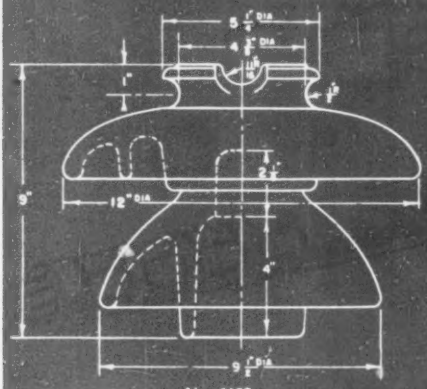
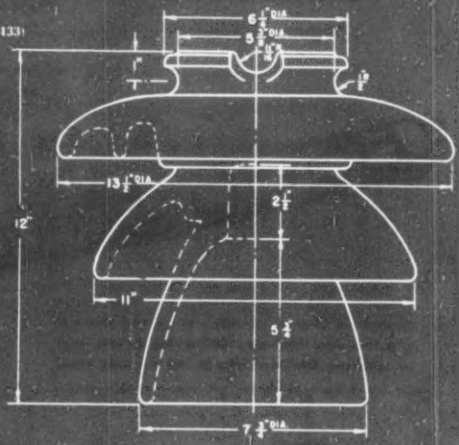


No. 6455
(Supersedes No. 6137)



No. 6469
(Supersedes No. 6138)

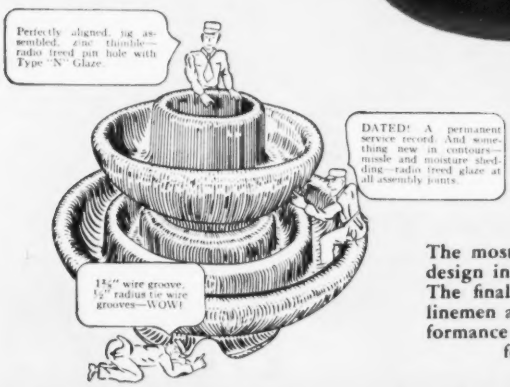
Porcelain Products, Inc.

Completely NEW!

IN DESIGN AND PERFORMANCE

BETTER
than anything you have ever seen or tried before.

The answer to John Lineman's Prayer.


Perfectly aligned, rig assembled, zinc thimble—radio freed pin hole with Type "N" Glaze.
DATED! A permanent service record. And something new in contours—missle and moisture shedding—radio freed glaze at all assembly points.
1¾" wire groove, ½" radius tie wire grooves—WOW!

A Complete Line to take care of Every Transmission Pintype Need.
(NEMA Standard)

The most radical departure from conventional insulator design in decades. Many designs were tried and tested. The final design is presented here. Utility Engineers, linemen and management will sing praises over the performance of these insulators for years to come. Write for folder describing the complete new line of Transmission Pintypes.

PARKERSBURG, WEST VIRGINIA

For PROVED WEED and BRUSH CONTROL...

Maintenance men have learned to rely on Dow Weed Killers for effective, economical control of annual and perennial weeds, stump sprouts and brush. Here's why! There is a *right* Dow Weed Killer for every common right-of-way maintenance problem.

Years of research by The Dow Chemical Company in cooperation with Federal and State authorities and with large utility companies have shown that when the *right* weed killer is *properly used*—good over-all results are obtained, resprouting nuisance is minimized, time and money are saved. Each of these superior Dow Weed Killers—proved by field trials and commercial usage—is produced and packed by Dow, leader in weed control chemicals for agriculture and industry.

Get all the facts! See your dealer — or write to Dow for literature.

AGRICULTURAL CHEMICAL DIVISION

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Dow Chemical of Canada, Limited, Toronto, Canada

ESTERON BRUSH KILLER *A powerful weed killer containing equal amounts of the Isopropyl Ester of 2,4-D and 245-T acid especially for use in controlling woody and herbaceous plants including alder, birch, brambles, elm, hickory, osage orange and many other species; assuring satisfactory control of most troublesome species on the average right-of-way. Available in 50-gal. drums and 5-gal. cans.*

2-4 DOW WEED KILLER, Formula 40 *A superior liquid amine salt formulation especially suitable for low volume spraying for selective weed control on turf and in crops. Does not clog nozzles—dissolves readily in hard or soft water. 1-gal., 30-gal., and 50-gal. sizes.*

SODIUM TCA 60% *Dow's newest vegetation control agent for killing grasses. Can be used in conjunction with the above Dow Weed Killers for control of both perennial grasses and weeds. Label recommendations should be followed. 375-lb. drum, 100-lb. lever pack, 50-lb. fiber pack sizes.*

DOW

CHEMICALS INDISPENSABLE TO INDUSTRY AND AGRICULTURE

DURAPOLE

Established 1892

57 YEARS OF CONTINUOUS SERVICE IN THE PRODUCTION • TREATMENT & DISTRIBUTION OF POLES

commenced its period of service when the Light and Power industry was young and has grown with it. has constantly made valuable contributions to protect the user's investment. Its 57 years of exclusive effort in the pole business has resulted in many pole improvements . . . FIRST BUTT TREATMENT . . . FIRST NON-PRESSURE FULL LENGTH TREATED MACHINE SHAVED AND SLAB GAINED POLE.

YOUR BEST POLE BUY IS . . . **DURAPOLE**

- MACHINE SHAVED
- FULL LENGTH TREATED
- SLAB GAINED
- GUARANTEED BUTT TREATMENT

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Western Yards and Treating Plants
Newport, Washington . . . Lumby, British Columbia

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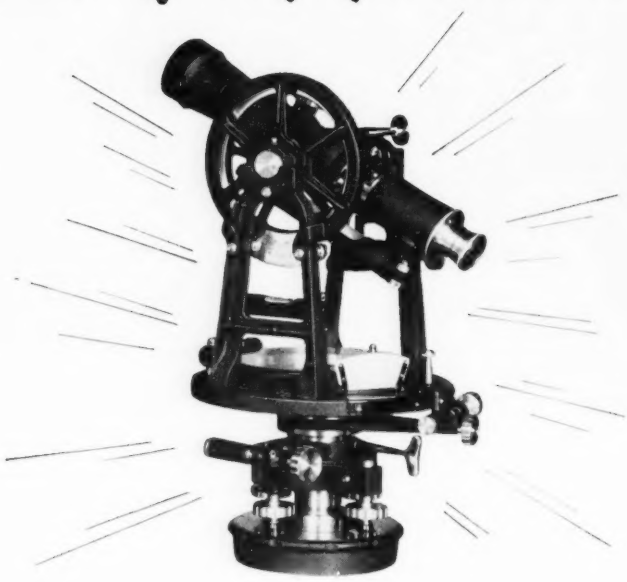
Back Again by Popular Demand



THE FAMOUS DAVID WHITE
Western Reconnaissance Transit

HERE IT IS — back in production at your numerous requests — and with many improvements. The Western Reconnaissance Transit, while moderate in price, is a high quality instrument particularly designed to serve many engineering and surveying purposes. While capable of distant focusing, it can also be used for close work, giving versatility.

No desirable features have been overlooked in the construction of the "Western." It is a standard instrument of precision, of the same exacting construction as our Engineers' Transits, yet offering a saving well worth while.

SPECIFICATIONS — No. 7064 TRANSIT

TELESCOPE: 9¼" achromatic terrestrial. *Coated optics. Objective lens* with effective aperture 1.141" — *Internal focusing*, erecting eyepiece with improved spiral movement for stadia wires. Magnifying power 20 diameters. Stadia wires fixed ratio 1:100 reading direct from center of instrument, the constant (f+c) being negligible. Ground spirit level to telescope, graduated 5" long; sensitiveness 60 seconds. Improved Clamp and Tangent Screw with counter spring.

VERTICAL CIRCLE: 4" diameter graduated to ½ degrees on solid silver, with double direct vernier reading to one minute, with removable aluminum guard to circle.

COMPASS: Gold plated needle about 3¼". Compass ring beveled graduated on solid silver to half degrees and numbered in quadrants. Compass box watertight, with variation ring.

HORIZONTAL LIMB: 5-5/16" diameter. Graduated on solid silver to ½ degrees, numbered 0°-360° in two ways, with double-direct vernier reading to one minute, with ivory hinged reflector — too fine spirit levels, sensitiveness about 75 seconds.

CENTERS: Bronze anti friction alloys, extra long and accurately fitted. Shifting center. Improved clamp and tangent, clamp and leveling screws of nickel silver.

FINISH: Black morocco enamel and lacquer.

EQUIPMENT COMPLETE: With strong aluminum base plate, sun shade, plumb bob, magnifying glass, adjusting pins, screw driver, oil can and brush, packed in fine polished hardwood case. Full length split leg tripod, 3½" 8 thread standard.

WEIGHT: Instrument 10 lbs., tripod 11½ lbs. *Note: Extension leg tripod No. 9070 extra.*

Write for name of our nearest dealer and our new bulletin No. 1048

DAVID WHITE COMPANY

361 W. Court St.
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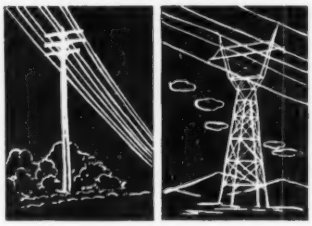

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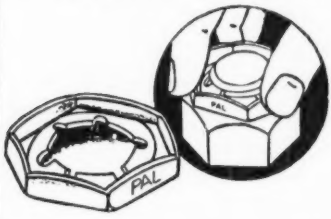

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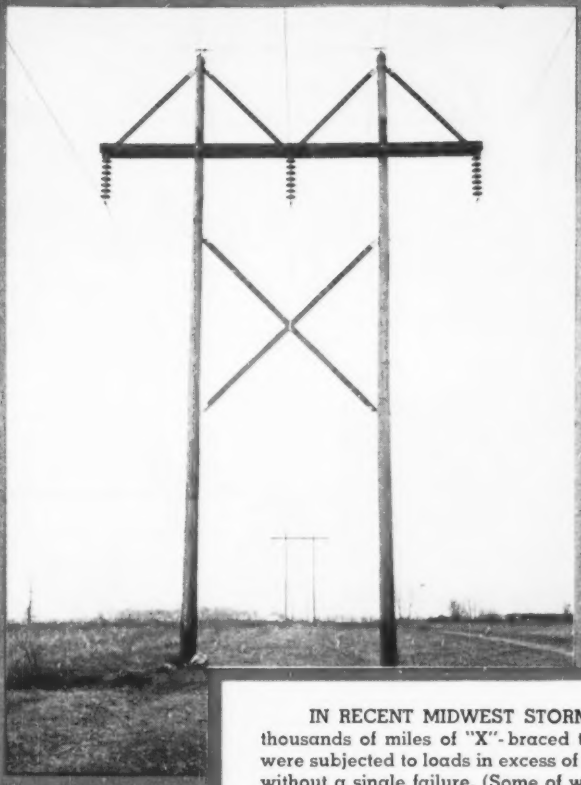

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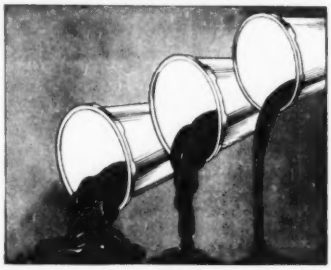

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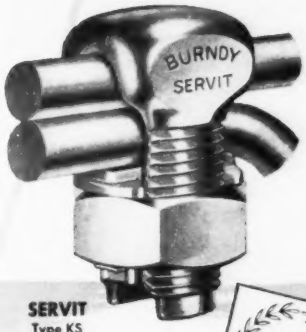

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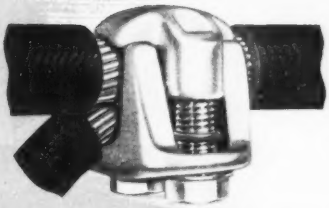

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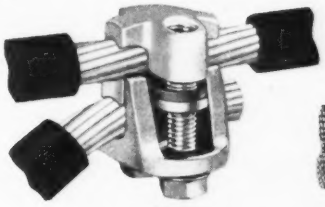

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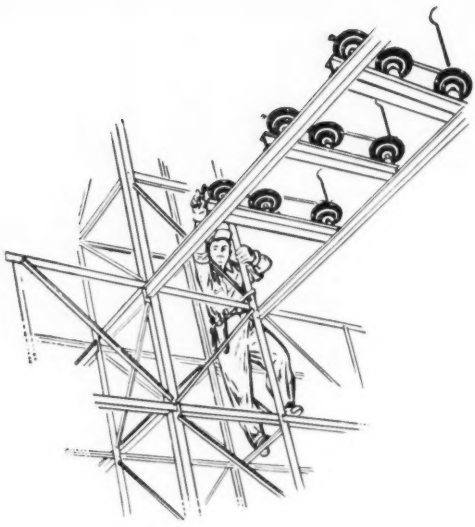

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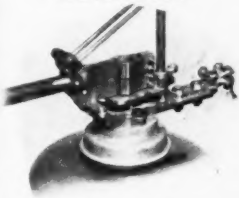

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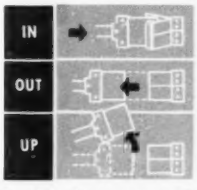

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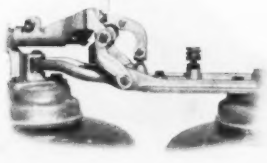

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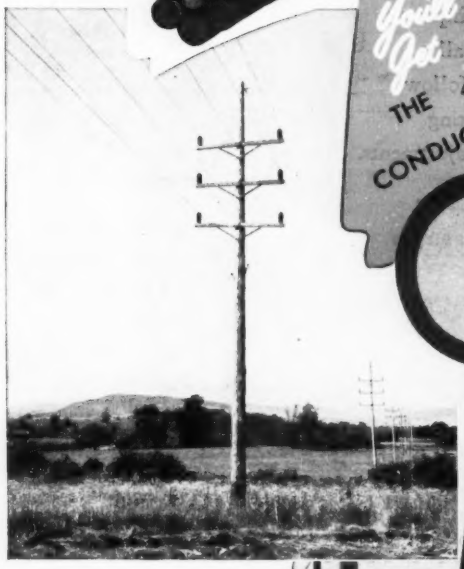

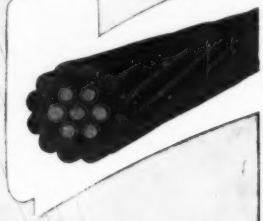

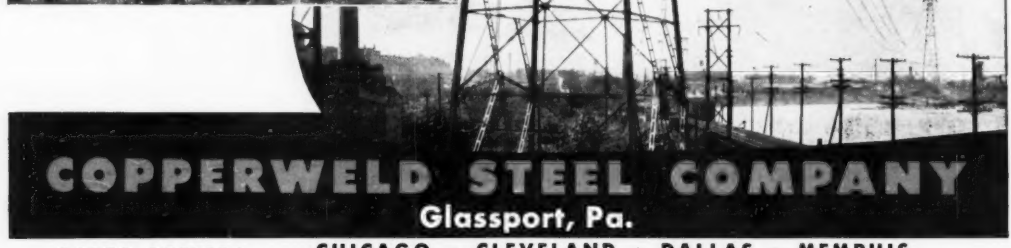

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GENERAL SYSTEM TECHNIQUES

PROTECTIVE RELAYING

SYSTEM GROUNDING

SYSTEM COMMUNICATION AND TELEMETERING

SYSTEM VOLTAGE REGULATION

Growth in power system loadings and area-coverage created an increasingly pressing array of problems in apparatus and line protection as well as in finding a coordinated answer to voltage regulation and transfer of operating information. Relaying in particular has undergone evolution and transition to prevent fault damage to the system and to minimize and localize the disturbances which otherwise would interrupt service. Grounding is an aspect of protection that has produced divergent schools of thought and techniques as means were sought to enhance the reliability of the power system. Early wire systems of communication have been extensively supplemented by carrier for talking and for telemetering as well as for transmitting relay and supervisory signals. Radio, even microwaves, are later tools. Off in another direction the overall system performance as to voltage regulation has reflected systematic advancement. The respective recitals record the details.

PUSH OUT
AND FOLD

Contributors to General System Techniques Section

H. P. Sleeper

Protective Relaying

Mr. Sleeper is Operating Engineer in the Distribution Department of the Public Service Electric and Gas Co and is past chairman of the Protective Devices Committee, AIEE; is active in the Power and Industrial Group, New York Section, AIEE; and is past editor of the *Relay Handbook Supplement*, NELA. He has to his credit several papers on the subjects of Protective Relaying and System Operation in ELECTRICAL WORLD and has presented papers on these subjects before the AIEE.

A. A. Johnson

System Grounding

Mr. Johnson, Central Station Engineer for the Westinghouse Electric Corp, is a member of the Transformer, Protective Devices, and System Engineering AIEE Committees. He is Chairman of the AIEE Subcommittee on Fault Limiting Devices and of Subcommittee #7 ASA Sectional Committee C42 on American Standard Definitions of Electrical Terms. He is also Chairman of several AIEE Working Groups. He has to his credit papers on grounding problems, series capacitors, voltage regulation, and other subjects in ELECTRICAL WORLD, AIEE, *Westinghouse Engineer*, and *Electric Light and Power*.

E. E. George

System Communication and Telemetering

Mr. George is electrical engineer, Ebasco Services Inc, and has been vice president of the Southern District AIEE, chairman of the Southeastern Division Apparatus Committee of NELA, and a member of other committees of the NELA, EEI, and AIEE. At present he is a member of the Power Systems Engineering Committee of AIEE. During the war he was electrical engineer of Southwest Power Pool. He has to his credit several papers on the general subject of system planning and system operation in ELECTRICAL WORLD, AIEE, *Electric Light and Power*, and CIGRE.

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System Voltage Regulation

Mr. Beller, is General Superintendent of Electrical Operations and Engineering and a member of the Executive Staff of The Cleveland Electric Illuminating Co. He is a member of the Transmission and Distribution Committee of the Edison Electric Institute, and Chairman of the EEI members of the Joint AIEE-EEI Working Group on Co-ordination of Construction and Protection of Distribution Circuits, and Sponsor of the Cable Operations Report. He is a member of the Association of Edison Illuminating Companies Power Distribution Committee, and several committees concerned with Interconnected System operation.

Protective Relaying

Early time-element schemes first supplanted by balanced relays, then distance relays appear followed by high-speed pilot and carrier. Ground-fault protection Remote tripping. Differential protection for apparatus. Gas and oil pressure response

PROTECTIVE RELAYING 25 years ago was simple in its tenets, usually employing simple overcurrent or directional overcurrent elements. Selectivity between units in series was obtained by the use of successive time increments usually employing inverse definite-minimum time induction relays. High-speed relaying of integrated high-voltage transmission systems was unknown.

About that time the advent of high-voltage networks and the interconnection of major power sources suffered restrictions due to the limitations of the relay protection. The chief drawback was the use of time-element schemes which allowed durations long enough to result in excessive damage at the point of fault, and severe voltage disturbances to all synchronous equipment, especially the generating units. Consequently high capacity ties between major sources were hazardous since fault occurrence frequently resulted in system instability. Distance relaying was still in the experimental stage and carrier relaying was just appearing in crude forms. Pilot wire relaying was in limited use but was uneconomical, and could not be employed over long distances. Improved relaying schemes of the high-speed type were definitely dictated if the economics of high-voltage network interconnections were to be exploited to any considerable degree.

TRANSMISSION LINE PROTECTION

Balanced Relay Protection

The first step to effect rapid disconnection of faulted transmission circuits appeared just about 25 years ago in the form of balanced relay protection. This scheme had the economic disadvantage of requiring transmission circuits to be constructed and operated in pairs between station buses. The currents from like phases of the parallel lines were compared either in a differential current relay or in cross-connected directional-overcurrent relays, which selectively identified the defective circuit. These schemes are shown schematically in Fig 1. After tripout of the first circuit the scheme suffered the disadvantage of employing only time-delay directional overcurrent protection of the second circuit. However, this scheme became very popular and the total fault-clearing time of approximately 15 cycles for the majority of fault locations on both lines gave excellent operating results. It became quite commonly used on circuits above 10 kv and is still used to a limited degree.

Relay developments accelerated rapidly in the '30's. The steadily increasing size of major power systems, the multiplicity of interconnections between systems, the increasing use of higher voltages for the transmission of bulk power, aggravated stability problems due to increased size of generating units and the concentration of short-circuit power, coupled with adverse customer reaction to voltage disturbances and service interruptions—all joined to stimulate the development of high-speed relays. These developments appeared in the form of distance relays, improved pilot wire relays and carrier current relays.

Distance Relays

This development appeared just about 25 years ago but did not find much acceptance until the high-speed feature was added to supplement the original proportional distance-time characteristic. As presently designed, this relay measures either the circuit impedance or reactance to the fault from a terminal and trips in one cycle if the fault is within 80 or 90% of the impedance length of the circuit. Faults in the remaining 10% (or 20%) of the line are cleared with a time-delay which is incorporated in an auxiliary element, or which, by virtue of a second distance element, is made automatically selective with adjacent circuits in the network. Thus a circuit protected with modern distance relays trips instantaneously at both ends for 80% of all faults, if set for a 90% reach on the instantaneous element, and trips with a time-delay for the remaining 20% of end faults. On two terminal lines, step-type distance relays utilizing three distance elements and set selectivity, as shown in Fig 2, give complete line and bus backup phase protection as far as the remote terminal and bus of the contiguous line section. Distance relaying em-

Prepared by H. P. SLEEPER, *Operating Engineer, Public Service Electric & Gas Co*
with the collaboration of W. R. Brownlee, Commonwealth & Southern Corp; L. F. Kennedy, General Electric Co; L. W. Marts, Public Service Electric & Gas Co; S. C. Leyland, Westinghouse Electric Corp

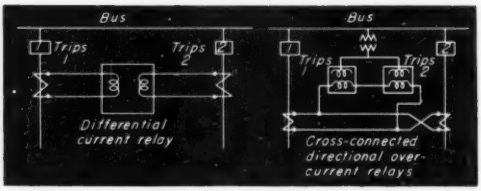

FIG 1—BALANCED-LINE relay protection in two forms

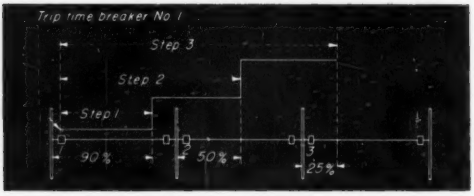

FIG 2—STEP-TYPE distance-relay setting diagram

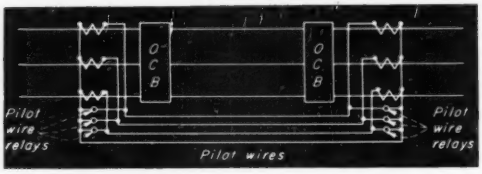

FIG 3—LOW-IMPEDANCE pilot-wire scheme

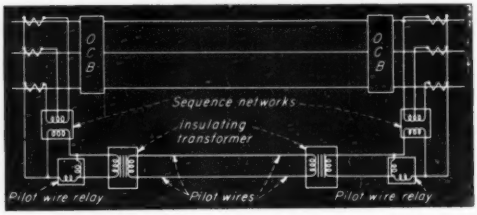

FIG 4—HIGH-IMPEDANCE pilot-wire scheme

bodying high-speed elements is one of the outstanding developments of the last quarter-century.

Distance Relay Applications

Distance relaying finds many applications in the protective art. High-speed distance elements are used as fault detectors, zone discrimination means and as back-up protection for phase faults in the standard distance-type carrier relay schemes. They are also used for bus and machine protection. However, one of the most common applications of these relays is to supplant time-element directional overcurrent relaying on moderate voltage networks up to 46 kv. While a large proportion of such circuits in the country are today protected by directional overcurrent induction-type relays, nevertheless distance-type relays are rapidly supplanting them especially on open-wire transmission circuits. The resulting speedup of operation lowers maintenance costs of the transmission circuits by reducing fault damage, minimizes voltage disturbances and consequently lessens customers' complaints. While more expensive than the directional overcurrent relay scheme, its operating results are far superior and the greatest economy through its use is realized in the resulting flexibility of the transmission system design. Sequential time-delay relay schemes seriously handicap transmission layouts to obtain time-selective schemes. The use of distance relays obviates this disadvantage and circuits may be laid out strictly as required for load-carrying or voltage-regulating purposes.

HIGH-SPEED RELAYING

Pilot Wire Relays

Three general fundamental improvements have been made in the protective relaying of high-voltage transmission circuits in the last 25-year period. These are: (1) Increased speed of operation; (2) increased sensitivity of fault detection; and (3) the simultaneous tripping of all terminal circuit breakers. High-speed (1 to 3 cycle) relaying of transmission network circuits was first accomplished with pilot wire relays. As originally designed, special relays were employed at each terminal of the transmission circuit and required interconnection of the current transformer secondary circuits between the terminals of the protected line. The scheme was technically satisfactory and gave good operating results. However, it was definitely uneconomical since it required large size copper conductors in the pilot circuits to circulate the secondary currents in all phases. Shown in Fig 3 is a schematic diagram of the original method of accomplishing this scheme using low-resistance pilot wires, three relays and four pilot wires being required per three-phase circuit protected. Shown in Fig 4 is modern pilot wire relaying where the current transformers at each terminal feed a positive and zero sequence network, which in turn develops a low voltage that can be applied to a single pair of small conductors between circuit terminals, usually of the telephone type which are frequently leased from local communication companies. One relay provides both phase and ground protection for one terminal of a three-phase line. Pilot wire relaying schemes rarely find application on transmission circuits more than ten miles in length. Pilot wire protection also affords simultaneous tripping of terminal breakers and is applicable to both two and three-terminal lines.

Carrier Current Relays

Carrier current relaying is the modern answer to high-speed relaying on 66-kv and higher voltage transmission circuits. It incorporates all three fundamental improvements of high-speed operation, increased sensitivity of fault detection and the simultaneous tripping of all terminal circuit breakers. Carrier relaying, especially using modified impedance type elements, can be made relatively immune to swing currents approaching out-of-step conditions while providing positive tripping in case synchronism is lost. The development of carrier

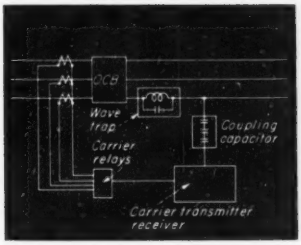

FIG 5—CARRIER-CURRENT relay protection

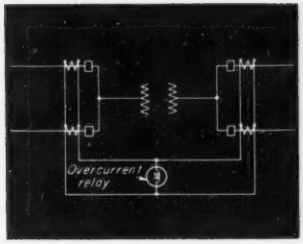

FIG 6—STANDARD differential relay protection

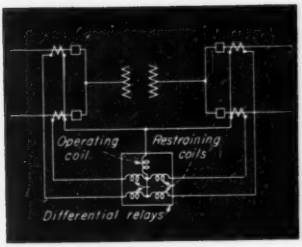

FIG 7—MULTI-RESTRAINED ratio differential protection

relaying, which operates in one to three cycles, was brought about largely by the necessary prohibition of major system disturbances caused by time-delay clearing of faults on the backbone of a major power system. Also, interconnection circuits between generating stations or contiguous integrated power systems today frequently require rapid fault clearing to maintain system stability; in addition high-speed circuit reclosing is often a vital necessity which requires high-speed relaying in order to effect rapid restoration before loss of synchronism occurs between generating plants or entire systems. Many such installations require fault detection, disconnection and restoration within a period of 15 to 20 cycles. Carrier current and pilot wire relaying offer the only solutions for this problem. A schematic diagram of modern carrier protection is shown in Fig 5.

Systems of Carrier Relaying

The directional-comparison distance-type carrier relaying scheme utilizes line current and voltage quantities to locate a fault. High-speed step-type distance elements measure the distance to the fault and act as fault detectors for the carrier relays; other distance elements provide time-delay backup protection for faults on adjacent line sections. During fault conditions a carrier signal is sent from each line terminal which blocks the remote end relays from tripping unless both sets of directional elements agree on an internal fault location. This stops the transmission of blocking signals which allows both sets of relays to trip.

The phase comparison scheme utilizes current only supplied from a sequence network fed from the line current transformers. During fault conditions half-cycle blocks of carrier at system frequency are transmitted between terminals and the relative phase angles compared in an electronic tube at each end. Tripping occurs when alternate half-cycles of blocking and tripping are reversed in time phase by an internal fault and tripping signals from both terminals coincide, with restraint eliminated. This more recently perfected form of carrier relay protection was the first type to be developed and originally appeared in 1928. Both types of carrier protection "fail safe" so that a failure of carrier causes tripping of the circuit to occur.

These systems are not cheap compared with standard relaying schemes. The necessity of using high-voltage wave traps and coupling capacitors as a part of the carrier communication channel between terminals, rep-

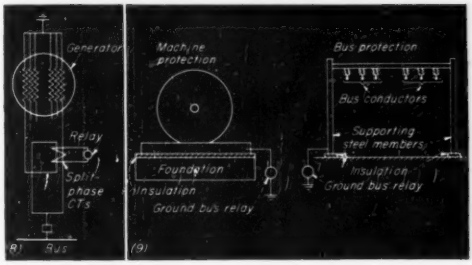

FIG 8—SPLIT-PHASE generator protector (relaying shown only for one phase)

FIG 9—GROUND BUS protection for machinery and buses

resents the principal reason for the higher cost of the carrier scheme. Perhaps one of the best opportunities for future development lies in the elimination of these devices or minimization of their expensive component parts. When this is done, the application of modern high-speed carrier relaying to lower voltage circuits should improve system operation.

Remote Tripping

The remote tripping of circuit breakers at the far end of a high-voltage transmission line is a new development in the past decade which has permitted marked economies in power system design. The omission of expensive high-voltage circuit breakers allows a line to be terminated in a transformer bank with the switching equipment on the low-voltage side only. Hence clearing of transformer faults requires the tripping of the breaker at the remote line terminal. The transformer protective relays effect this by transmitting a tripping signal to the remote terminal by means of pilot wires or a carrier current pilot channel. To minimize the possibility of false tripping by foreign voltages when the carrier channel is used, it is common practice to introduce an intentional time delay of 12 to 30 cycles, or to employ a chain of coded signals or one or more audio frequency time signals, to effect tripping of the remote terminal circuit breakers. All of these schemes have the disadvantage of adding a time-delay to the transformer protective scheme and some susceptability to false tripping has been experienced in practice. An alternative is to install a high-voltage short-circuiting or grounding switch on the line at the transformer terminal. This

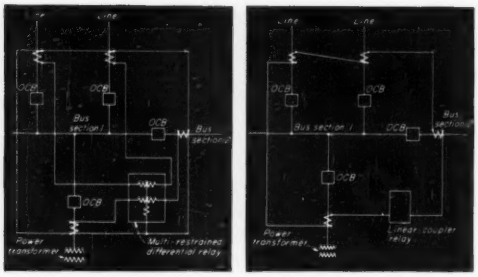

FIG 10—BUS DIFFERENTIAL PROTECTION scheme (left) using multi-restrained relays. Schematic diagram (right) of bus differential relay using linear-coupler transformer

switch is automatically closed by the operation of the transformer differential relays. This causes operation of the regular line relays at the remote terminal without adding complexities to the protective schemes.

Ground Protection

The problem of the ground relay protection of high-voltage or low-voltage transmission and distribution systems was not present to any great extent 25 years ago because all electrical systems were either ungrounded or solidly grounded. The former did not entertain the problem; the later in general avoided the problem because phase relays were usually adequate to operate because of the high currents which resulted when ground faults occurred. However, the introduction of neutral resistors or impedors changed this picture and resulted in the development of many schemes of elaborate, sensitive and high-speed ground relay protection. In general, such schemes employ all the principles previously discussed. The utilization of the zero sequence network, with its inherent independence of phase load and fault currents, has greatly increased the sensitivity of ground relays, and has thereby improved materially the relay protection of high-voltage transmission systems where more than 80% of all faults are initiated to ground. Special systems of super-sensitive ground relays have been developed to detect faults on very high impedance neutral grounded systems and even on ungrounded transmission and distribution systems. Many further improvements in ground relaying in the future are indicated, and this art is rapidly developing, particularly in the direction of distance type ground relays.

Transformer Protection

Modern high-voltage, large capacity power transformers, frequently involving several voltage windings with parallel windings per phase, are universally protected by some form of differential relays, of which there are several available. In its original form differential protection was accomplished merely by balancing an overcurrent relay across current transformers located on the two sides of the protected equipment. A schematic diagram of that scheme is shown in Fig 6.

About 25 years ago this was improved by bringing all current transformer circuits into the relay and using restraining coils to bias the characteristic of the relay, so that tripping was effected when a ratio of input to output current was attained instead of when a fixed value of differential current appeared in the relay. The slope of the percentage curve was made adjustable. This improved the operation of the relay by minimizing the effects of errors which would cause false operation, such as current transformer characteristic differences, current transformer ratio errors, and the effect of iron saturation in current transformers, without sacrificing sensitivity for fault operation. In its more modern forms this relay has been improved by the use of a non-linear ratio characteristic requiring a greater percent unbalance to operate at higher short-circuit currents, and by connecting the individual current transformer secondary leads to separate restraining coils. The latter arrangement insures restraint during external faults regardless of the switching setup. A schematic diagram of this is shown in Fig 7. This significant development has greatly improved differential relay operation and has enabled high-speed differential relays to be used without danger of false operation on all kinds of rotating and static electrical equipment operating at all voltages.

Magnetizing Current Inrush

Development of economical power transformer design to make maximum use of improved iron characteristics in transformer cores has in recent years made more acute the problem of coping with magnetizing current inrush when a transformer is energized without load. This frequently results in a high peaked current inrush accompanied by a d-c offset wave which tends to cause improper operation of differential relays. Incorrect tripping may be avoided by the use of desensitizing or lockout auxiliary devices which retard or prevent operation of the differential relays for a predetermined time. The use of such auxiliary devices may be avoided by the use of a differential relay which is inherently insensitive to the components which cause the trouble. One relay which accomplishes this is the harmonic-restrained relay wherein incorrect operation is prevented by the use of a restraint element which is responsive to the proper harmonic components of the current wave and to the d-c offset energy. This scheme employs standard types of current transformers and constitutes an effective form of percentage differential relay protection. Standard differential relay connections are used.

Thermal relays provide an additional form of protection for power transformers which may be used to protect them from overheating as a result of sustained overload or fault conditions. Today, transformers are being operated at higher temperatures than in the past, especially when emergencies occur. Under these conditions, the development of dangerous hot spots may be prevented by using thermal relay devices to simulate and reproduce the temperature conditions in the windings and are frequently located within the transformer cooling oil. Economical application of these devices lies in unattended stations where overloads cannot be relieved manually.

Oil and gas pressure relays constitute a simple, non-electrical form of transformer protection. They receive their operating impulse from the accumulation of gas

or the development of an oil pressure wave within the transformer tank. The gas or oil pressure operates a bellows which completes the electrical tripping circuit. These devices have found favor abroad, and to a limited but expanding extent in this country. Such protection is especially effective if differential protection cannot be applied economically.

Generator Protection

The universal practice of using differential protection on generators dates back many years. The original protection was the same as described in connection with power transformers, illustrated in Fig 6. This scheme lacked speed of operation and the sensitivity required to detect faults at all points in the winding, and thus limit iron burning to a minimum. Modern generator differential relays are of the high-speed type and are extremely sensitive to internal faults. When faults occur external to the zone of the relay protection, the increasing slope characteristic prevents incorrect operation.

Synchronous machines of all types may suffer serious damage if caused to run out-of-step for any reason, even for very brief periods. Out-of-step relays to trip the machine are frequently applied to large generators, frequency changers, synchronous condensers and occasionally to large motors to prevent damage when pole slipping occurs. Special relays have also been developed in the past 25 years to protect against the motorizing or loss of field on large generators.

Where generators are connected directly to transformers it is possible to obtain extremely fast and sensitive ground protection if the machine is grounded through a high impedance. An elementary overcurrent or overvoltage relay can be used to provide a protective scheme inherently unaffected by through faults.

Bus Protection

On earlier power systems the relay protection of station buses was not considered a problem. Faulted buses were disconnected from the system by the relaying out at the source ends of the lines feeding the defective bus. As systems expanded and the feeders to buses increased in number and capacity, the required higher line relay settings resulted in excessive fault damage, increased shock to the system, and necessitated relief. Many schemes of bus protection have been developed in the past 25 years, among which are (1) the impedance bus protection scheme, which utilizes standard impedance relays on each circuit breaker connected to a given bus section (this constitutes an economical method where the presence of suitably located reactors permits); (2) the directional ground interlock bus protection scheme, wherein directional ground relays on each breaker connected to the bus are polarized toward the bus and interlocked with each other and with a neutral ground fault detector; (3) the ground bus scheme; and (4) the commonly used bus differential scheme.

The bus differential scheme is one of the oldest and the most commonly used types of bus protection employed today, embodying as it does simplicity, economy and dependability. The development and application of differential relays on buses have paralleled that of transformer differential relays previously described. In practice the relays for both applications are similar and frequently identical. A schematic diagram showing multi-restrained bus differential relays applied to a standard bus layout is shown on Fig 10.

Current transformer saturation offers problems in connection with all forms of differential protection, especially bus protection. When a through fault occurs the current transformer on the faulted circuit will carry a much higher current than the other current transformers connected to the bus section. Saturation of the current transformer iron results in distortion of the wave form which tends to cause improper operation of associated differential relays. One solution to this problem is to use a multi-restrained differential relay with a non-linear ratio characteristic which requires a greater percent unbalance to operate at higher short-circuit currents.

The use of linear couplers instead of current transformers is another solution to the same problem. These are in effect current transformers without iron and hence all saturation effects are eliminated. All couplers on a given phase are connected in series with each other and with a simple instantaneous over-voltage relay (Fig 10). The coupler voltages are proportional to the load current and under balanced conditions no voltage appears on the relay. An internal fault causes a differential voltage to operate the relay. The simplicity of this scheme must be balanced against the necessity of using special coupler devices in protected circuits.

A promising new development which has the advantage of using standard current transformers employs a high impedance relay and a series resonant circuit. This is designed to eliminate the ill effects of current transformer saturation and of the presence of a d-c offset in the current wave.

Electronic Relaying

Electronic relaying is a comparatively recent development and today is being employed largely in an auxiliary capacity only. Theoretically all protective relay discriminating functions can be performed in a vacuum tube circuit which has the inherent advantages of accurate control, negligible inertia, and absence of friction in moving parts. Disadvantages are the complexities of wiring and testing.

Relays of the simplest overcurrent and directional overcurrent types used 25 years ago did not require an accurate knowledge of short-circuit currents involved if minimums were obtainable. Modern relay systems, however are dependent upon a reasonably accurate knowledge of the system quantities during fault conditions. A new engineering tool which came into common use in the '30's was the method of symmetrical components for the computation of unsymmetrical faults. This important contribution, originally introduced generally in this country by Mr. C. Le G. Fortesque, has made possible many significant developments in the protective relay art and in the applications of protective relays to the component parts of modern electric power systems.

System Grounding

Interconnections required grounding. Limiting transient overvoltages during faults. Merits of various schemes for various types of system. Selectivity and stability. The Petersen coil. Statistics of prevailing practice

SYSTEM GROUNDING, even after sixty years of operating experience with a-c systems, poses a major problem to the engineer trying to select a grounding method having all advantages and no disadvantages. During the past 25 years, however, great progress has been made in understanding the factors involved, but disagreements and conflicting ideas no doubt will continue to exist.

Isolate or Ground?

In the early years the main question was whether the system neutral should be isolated or grounded. Since a grounded neutral is not required to transfer power, it was natural that many of the first power systems were operated with isolated neutrals; a line-to-ground fault would not cause a circuit outage. Effective ground relaying was practically unknown, and circuit breakers were not too dependable; thus many station troubles and prolonged circuit outages due to grounds were avoided by isolated neutral operation which would not have been the case with the neutral grounded. There were less equipment failures on the grounded systems, however, because the same insulation levels were used on both types of systems.

Interconnections Needed Grounding

As long as power systems were small and operating voltages were relatively low, ungrounded operation was generally satisfactory. But as systems grew, with more and longer feeders and higher voltages, new operating problems with the isolated neutral became evident. Line-to-ground faults, particularly in cable systems, had sufficient charging current to ground to cause serious damage at the point of fault resulting in phase-to-phase or three-phase faults. Arcs to ground, which were not self clearing, became more prevalent, causing transient overvoltages which frequently caused a failure of generator or transformer insulation and blew up lightning arresters on the same circuit or elsewhere on the system. Such simultaneous failures often caused two or more circuits to trip from the system. Faults became more difficult to locate. Operating the longer lines with ground faults for extended periods of the time caused interference with communication circuits. Broken wires were more of a hazard to public safety because power circuits were covering larger areas.

Arcs to Ground

The arc-to-ground or arcing-ground phenomenon was the biggest enemy of isolated neutral operation and therefore most systems which suffered from this ailment were changed to grounded operation, either solidly or through resistance. Systems operating at generator voltages and those supplied by transformers at 25 kv and below were first grounded through resistors. Generally a relatively low value of resistance ohms was selected to provide sufficient current for selective relaying of ground faults.

On some delta-connected systems grounding transformers were installed to provide neutrals which could be grounded.

Solid Grounding Tried

Solidly-grounded systems were free from arcing-ground troubles, but considerable damage occurred usually at the point of fault in cables and equipment because of slow speed relays and breakers.

By 1924 many systems had been grounded through resistors, both grid type and water barrel, with generally favorable results. Some had been solidly grounded with moderate success. A few had been grounded through reactors about which little is known. Ground-fault neutralizers (Petersen coils) were just making their appearance here. Many systems were still ungrounded, but the number was decreasing.

Problems During Past 25 Years

Twenty-five years ago power systems were on the threshold of enormous growth (Fig 1) and since system grounding affected equipment insulation and con-

Prepared by A. A. JOHNSON, *Central Station Engineer, Westinghouse Electric Corp*
with the collaboration of A. M. deBellis, Consolidated Edison Co of N. Y.; J. H. Foote, Commonwealth & Southern Corp; E. Hansson, Penn. Water & Power Co; P. A. Jeanne, Bell Telephone Laboratories, Inc; A. A. Kronebera, Southern California Edison Co; W. W. Lewis, Union College; F. R. Longley, West Mass. Electric Co; J. B. McClure, General Electric Co; S. H. Mortensen, Allis-Chalmers Mfg Co; C. T. Sinclair, Duquesne Light Co

tinuity of service, more attention was being given to grounding methods. All known factors received careful attention and efforts were being made to secure greater freedom from all types of faults as well as to reduce disturbances from faults which did occur.

Shown in Fig 2 are several commonly used present-day methods of grounding.

Factors Affecting System Grounding

1. *Transient Overvoltages*

Transient overvoltages as high as five times normal peak line-to-ground voltage caused by arcs to ground and switching surges had already been proven by field tests. The transient voltage phenomena, however, were still subject to controversy and many laboratory studies by different investigators proved that transient overvoltages could be produced, and also suggested general rules whereby overvoltages could be limited to safe values by proper grounding.

For reactance-grounded systems, which incidentally includes solid grounding and grounding transformers, the ratio of zero-sequence reactance to positive-sequence reactance at fault points gives a measure of whether the system is safe from excessive transient voltages. On generator systems the acceptable maximum ratio of X_0/X_1 has varied from three to ten. Ratios between one and three are the most commonly used since they are the safest and usually allow the application of 80% lightning arresters at the generator terminals. Ratios above three or four, however, are still subject to controversy for generator system.

Sequence Component Ratios

Operating experience has proven that when ratios of X_0/X_1 in excess of ten are used, there may be trouble due to double faults similar to that for ungrounded operation. On systems without directly-connected generators the ratios often are higher than ten where the system is grounded through a grounding transformer. This is accepted as practical because oil-insulated transformers have relatively more insulation for the same operating voltage than do generators or motors.

Resistance grounding limits transient overvoltages but allows practically full neutral displacement during line-to-ground faults. This neutral displacement did cause double faults which have been eliminated practically by providing system insulation which will safely withstand line-to-line voltage to ground.

Ground-fault neutralizer grounding also limits transient overvoltages but, like the resistor, it allows full displacement of the neutral during line-to-ground faults.

Transients During Faults

Potential transformer grounding, ungrounded and grounding through high values of reactance are undesirable measures because of the possibility of high transient voltage during ground faults and other disturbances. In several cases a high ohm neutral reactor was shunted by a parallel resistor. This proved ineffective because in order to limit transient voltages to safe values the resistor ohms required were so low that the reactor could be eliminated.

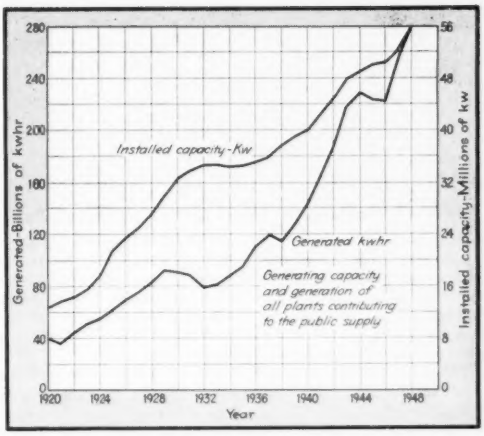

FIG 1—GROWTH of installed capacity and output of plants contributing to public supply

Transient overvoltage phenomena are of random occurrence and do not occur unless the system is disturbed by a fault or a switching operation. They involve arcs in oil, air and other types of insulations under widely varying conditions. Thus a poorly-grounded system may have escaped troubles simply because the required arc conditions have never occurred. Therefore, engineers have relied more and more on the development of laboratory tests and techniques to determine the characteristics of grounding devices which will minimize troubles from transient voltages.

2. *Apparatus and Circuit Insulation*

Apparatus and circuit insulation is affected by the manner in which the system is grounded in two basic ways. First, the insulation must be capable of withstanding rms voltages greater than those which the grounding method will allow, and second, the surge strength of the insulation must be high enough to be protected by available surge protective devices.

To accomplish these aims, the last 25 years has covered a tremendous growth on insulation testing, insulation improvement and insulation protection. The characteristics of lightning surges were determined, surge testing laboratories were standardized, and basic insulation levels for the different voltage classifications were established. Through these developments and the use of proper grounding, it is possible to select insulation levels which can be protected from surges. Systems operating at 115 kv and above may and have used graded insulation to various extents.

In cable systems it is the practice of some companies to provide insulation in accordance with the type of grounding used. A maximum insulation would be used for ungrounded or resistance grounded systems and the minimum insulation is required on solidly or effectively grounded systems.

3. *Damage at Point of Fault*

At first when generator systems were grounded, some

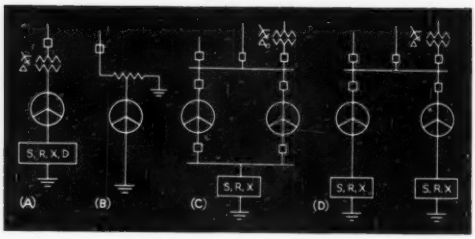

FIG 2–COMMONLY USED METHODS of grounding generators and transformers: (A, B) Unit type system; (C, D) Two or more generators with and without feeders at generator voltage; S = solid grounding; X = reactor grounding; R = resistor grounding; D = distribution transformer with secondary resistor

neutral resistors were destroyed due to slow clearing of faults and solid grounding caused excessive fault damage. In a few cases excessive burning of generator stator iron was caused by generator faults.

Because of improvements in relays and circuit breakers, there was a tendency to solidly ground more generator systems. Where the neutral is solidly grounded, more current will flow through the faulted winding for a line-to-ground fault than will flow for a three-phase fault. Because generators are designed to withstand three-phase faults only at their terminals, a neutral device should be used to limit line-to-ground fault currents. This practice began to develop in the early thirties and since that time solid grounding of generator neutrals has decreased.

Limit Ground Faults

There is now general agreement that a generator neutral device should limit line-to-ground fault currents as much as possible and at the same time be suitable in other respects in order to minimize damage to generator iron if a ground fault should occur in the generator. Practically all faults which have occurred in generators have been from line-to-ground.

Several cases of damage to generator bearings have resulted from heavy line-to-ground faults within the generator winding. Sufficient voltage occurred to break down the bearing insulation and the currents which flowed pitted the rotor bearing surface requiring a refinishing job.

On systems operating at voltages higher than generator voltage, the philosophy of grounding is different because practically all faults involve flashovers between open wires or across insulators where the damage is usually of minor significance. Thus solidly-grounded high-voltage systems have developed and grown almost without exception in the voltage classes above 70 kv. A large percentage of systems in the 22 to 70-kv class are solidly grounded indicating that it is acceptable practice.

4. *Relaying for Ground Faults*

When generators were first grounded the allowable ground current was determined almost entirely by the relaying. If the relaying used for line-to-line fault protection were also to be used for line-to-ground faults, the neutral was grounded through a resistor to allow three to five times the load current of the largest feeder. Where residual ground relays were to be used, it was considered desirable to keep the ground current approximately equal in magnitude to the full load current on the largest feeder to obtain the best operation of the ground relays.

Ground relaying was at first rather direct and simple because each system was grounded at one station. However, as the systems increased in size and several stations, each with its own ground, were interconnected, ground-fault currents could not be selected by a simple overcurrent relay and directional relays were required. This still did not solve many of the situations involving relatively short parallel feeders and the pilot wire relay was developed in the late thirties. About the same time percentage differential relays appeared and better protection could be applied to the generator windings.

Fault Selectivity

Today after over 30 years of development, relays are available with accurate selectivity for line-to-ground faults on practically any type of grounded system which gives enough current to make the relays operate. Also, the use of symmetrical components and the A-C Network Calculator have simplified the problems of determining the proper relaying for faults involving grounds.

The same general principles in applying ground relays to generator systems are also used on high-voltage systems except that carrier current generally replaces the pilot wire over long distances to get simultaneous tripping of both ends of a faulted line. Directional ground relays and ground impedance relays have been perfected to a high degree.

5. *Stability*

High-speed relays and breakers have made it possible to meet practically all stability problems involving line-to-ground faults and also most phase-to-phase and double-line-to-ground faults. On a few systems the neutral was grounded through a resistor at the sending end to give additional power loss during a line-to-ground or double-line-to-ground fault, to help stability.

Solid grounding of high-voltage systems has made it possible to apply single pole reclosing circuit breakers which improves system stability, because only the phase which is faulted to ground is opened and reclosed. The two good phases carry current while the fault is being cleared.

6. *Mechanical Stress in Equipment Windings*

Solid grounding of generators is not acceptable according to ASA Standard C50, because more current can flow in the generator winding for external line-to-ground faults than for three-phase faults. This rule has not been universally followed, because today a number of generators operate with solid grounding. A large proportion of the solidly-grounded machines, however, are on the unit type of system where all of

the power is stepped up through power transformers. Since in the unit system there is very little exposure of the connections between the generator and the transformer, the risk of solid grounding has been accepted in some cases.

Mechanical stress in transformer windings for solidly-grounded systems is of relatively minor importance since the windings of transformers with four per cent impedance or more must be built to handle three-phase faults. In special types of transformers, such as three-winding units, the design of the windings must consider ground currents and in some cases additional strength may be required in the construction of the delta winding for this reason.

For all types of grounding except solid grounding mechanical stress due to ground-fault currents is a relatively unimportant factor, because the equipment must be designed to withstand three-phase fault currents.

7. *Lightning Protection*

The fundamental purpose of lightning arresters, fixed gaps, protector tubes or any other such device is to bypass lightning around insulation. To achieve this objective, application principles for lightning protective equipment have developed and progressed along with those for system grounding.

When distribution systems and generator systems were first solidly grounded, arresters of reduced rating were often applied. Where the systems were ungrounded or grounded through resistors, full rated arresters were used. On ungrounded systems many arresters failed because of high transient voltages.

Arrester Rating

On systems 20 kv and higher the first arresters were rated full line-to-line voltage regardless of how the systems were grounded. During the twenties high-voltage arresters were improved tremendously and reduced rated arresters were applied on solidly-grounded high-voltage systems. Since that time better arresters have been developed until today the impulse levels of high-voltage transformers are practically dictated by what protection an arrester can provide and the margin of protection desired.

8. *Field Reduction*

Prompt reduction in generator field current is essential to limit the damage at the point of fault in generator circuits, because as long as there is field current, voltage is generated and fault current will flow. Field discharge devices have been used for many years.

9. *Line Availability*

On each of the various types of grounded systems except underground systems of small extent, or systems grounded through tuned reactance, a momentary fault from one phase to ground requires a circuit outage to clear the fault. On a number of systems automatic reclosing circuit breakers, single pole and three pole, are used which for flashovers clear the fault and immediately reclose, restoring service. Thus the

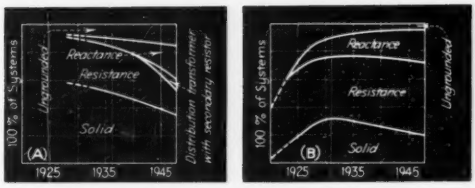

FIG 3–GENERATOR GROUNDING PRACTICES over past 25 years. Percent values between the curves show relative prevalence. (Data from recent AIEE report.) "Ungrounded" includes potential transformer grounding: (A) Without feeders at generated voltage. Includes the unit system and two or more generators feeding step-up power transformers. Covers 337 generator systems as of 1947; 250 are of the unit type. (B) With feeders at generated voltage. Includes generators feeding local circuits with or without step-up power transformers. Covers a total of 123 systems as of 1947

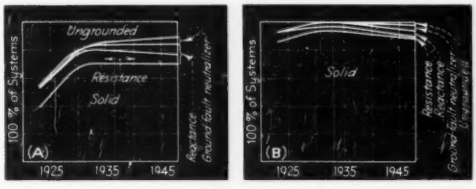

FIG 4–GROUNDING PRACTICE on high-voltage power systems. Percent values between the curves show relative prevalence of various grounding methods. (Data from recent AIEE report) "Ungrounded" includes potential transformer grounding. (A) 22- to 70-kv systems (443 systems as of 1947). (B) 71-kv and up systems (124 systems as of 1947)

grounded system by using fast reclosing breakers approaches the effect of ground-fault neutralizer grounding.

Some of the temporary flashovers involve more than one phase. In such cases three-phase reclosing breakers will clear the fault whereas the ground-fault neutralizer will not.

10. *Adaptability to Interconnection*

Systems grounded solidly, through reactance or through resistance are adaptable practically without limit to interconnection. On the other hand, a ground-fault neutralizer system cannot conveniently be tied in with other systems, since if conductively connected, the tuning is destroyed and arc suppression would not be obtained. Ungrounded systems are subject to the same difficulty, in that connection to a grounded neutral system destroys the advantages of ungrounded operation, leaving most of the disadvantages.

The higher voltage systems in the United States, with few exceptions, are solidly grounded, and one of the big factors which influenced this is adaptability to interconnection. Some systems which had resistance grounding and ground-fault neutralizer grounding have been changed to solid grounding in order to be able to tie in with neighboring systems.

Since practically all interconnections involve transmission lines, the grounding of generator systems and distribution systems has little or no effect on this problem except in isolated cases. Usually the same

principles would apply, however, as for transmission systems.

11. *Neutral Breakers*

The purpose of an automatic neutral circuit breaker is to disconnect the neutral of a generator from ground on single-line-to-ground faults within the differential relay zone of the generator. Some neutral breakers are in service, but there are probably more generators without automatic neutral breakers than with them. Automatic neutral breakers, however, are particularly important for generators with long time constants which are either solidly grounded or grounded through a reactor.

Neutral breakers are not required in transformer neutrals.

12. *Equipment Costs*

The solidly-grounded system without an automatic neutral breaker is the least costly. On solidly-grounded high-voltage systems there also may be a saving in apparatus insulation. In the case of 230-kv transformers and higher, the saving resulting from the use of graded insulation is greatest with smaller savings down to and including 115 kv. The reactance grounded systems probably come next in cost with resistance grounding about the same.

On generator systems of the unit type, the distribution transformer with secondary resistor grounding device is less costly than either a neutral reactor or resistor.

With reactor or resistor grounding of high-voltage systems some grading of the insulation may be possible. The ground-fault neutralizer may cost more or less than a neutral reactor or resistor, but grading of the transformer insulation is limited to the system line-to-neutral voltage.

Arrester Outlay

Lightning arrester costs on resistance grounded, ungrounded and ground-fault neutralizer grounded systems will be more than for solidly-grounded systems. If the ratio X_0/X_1 at the point where the arresters are applied is three or less, usually an 80% arrester can be used. If the X_0/X_1 ratio is higher than three, a check must be made to determine if an arrester rating below that required for line-to-line voltage can be applied; thus the cost is determined by the effectiveness of the system grounding.

Solidly-grounded systems in the voltage classes 115 kv and above may use reduced insulation levels in transformers in addition to the grading of the insulation. This further reduces the cost of transformers and in the higher voltage systems reduction of insulation may also effect savings in line construction.

13. *Inductive Coordination*

Ungrounded system with non-clearing faults have caused interference with communication circuits. Also ground faults on solidly-grounded systems have induced fundamental frequency voltages in communication circuits which caused operation of protective devices and at times caused hazard to workmen. Certain grounded systems have caused interference due to harmonic frequencies generated on the power system. A few cases of interference have occurred on grounded systems with shunt capacitors.

The type of neutral grounding may have an important bearing on the induction experienced in a given situation. However, no particular type of neutral grounding may be considered a cure-all, and in a particular situation, the equipment or system producing the interference must be studied as well as the communication circuits which are affected. Remedial measures applicable may involve reduction in the supply circuit influence, reducing susceptiveness of communication circuits, changing the coupling between the two systems or a combination of two or all of these measures.

Inductive coordination was a contributing factor, and in some cases an important factor, in the use of resistance grounding particularly in the early years when relays and circuit breakers were slow. Modern high-speed fault clearing has reduced the importance of neutral resistance (or type of system grounding) as a coordination measure as far as fault currents on the system are concerned.

Summary of Grounding Practice

According to a recent survey of Grounding Practices on Power Systems made by the American Institute of Electrical Engineers, the block diagrams in Fig 3 and 4 summarize the manner in which generator systems (11 kv and above) and high-voltage systems (22 kv and above) are grounded.

Generator systems have been divided into two classes, those with and those without feeders at generated voltage. The trends shown on the curves are definitely away from solid grounding and reactance grounding is increasing. On the unit system, the use of the distribution transformer with secondary resistor is increasing rapidly as the number of systems using this device will double within the near future. In addition, a number of the potential tranformers now used have their secondaries loaded with resistors to minimize the effects of arcs-to-ground and switching surges.

Transmission Grounding

Transmission systems of 22 to 70 kv, shown in Fig 4A, are about 70% solidly grounded with the rest divided between all other methods. Ground-fault neutralizers show some increased use during recent years, but there is no definite indication that this device will be used on a large scale.

For systems 71 kv and above, shown on Fig 4B, practically all are solidly grounded.

There are few records on grounding of power or distribution systems below 11 kw. It is known, however, that all methods are in use and that solidly grounded systems are probably 75% of the total. As for industrial plants, many operate ungrounded in order to continue service during line-to-ground faults or with resistance grounding in order to limit fault current to that necessary for relaying and thereby minimize damage due to excessive current.

System Communication And Telemetering

Carrier art began 25 years ago. Unified communication soon began to unfold
Radio has paralleled. Telemetering evolved over same quarter century
Point to point microwaves seen as escape from channel congestion

THE ENTIRE ART of telemetering on electric power systems has developed within the last 25 years. The same period covers almost all of the history of power system communication. Let us look at both of them in their infancy. Communication will be considered first because most of the channels suitable for communication were later found suitable for telemetering. The development of telemetering from this standpoint is largely the development of sending and receiving equipment.

In 1924, carrier current communication over transmission lines was being tried out on half a dozen or more transmission utility systems. The equipment was so experimental that it is difficult to assign any definite year as the time when carrier current communication became commercially practicable. However, the period 1920 to 1925 covers this stage of development.

Complicated but not Refined

By present day standards, power company carrier equipment in 1924 was amazingly complicated and indirect in its approach to the requirements. Among the usual items were: A 1500-v three or four unit motor-generator (for power supply), double frequency operation, antenna coupling, loud speaker calling and four-wire terminals. There was no automatic volume control, no squelch control, no traps, no coupling capacitors, no frequency stability, no wiring diagrams, no bill of material, and no spare tubes or parts this side of the factory.

Load dispatchers alternated between swearing by the equipment and swearing at it. In emergencies, the carrier telephone frequently provided the only means of communication with important outlying substations and power stations. More frequently, carrier equipment failed to work or worked so poorly at unexpected times that its availability was strictly a gamble. Radio men knew little about power systems, and power men conversely stayed on the right hand side of the kilocycle decimal point.

Active Development

In the ten-year period beginning about 1918, the General Electric, Westinghouse, and Western Electric Companies engaged actively in the development of power line carrier. Although the Western Electric carrier was withdrawn from the market after the end of this period, many of the special features of its design such as single side band modulation, suppressed carrier, high audio quality, and low noise to signal ratio were "rediscovered" and utilized ten or fifteen years later when the power equipment manufacturers made several basic improvements in their products then coming into very general use.

Power system carrier communication in the period around 1924 usually comprised a magneto land-line network, backed up by (but not interconnected with) commercial service from the local telephone company. Power company and telephone company long haul facilities were largely open wire and were much different from what they had been ten years earlier. The power system telephone lines were usually on transmission or distribution poles or on power line right-of-way, and therefore exposed to coincident hazards with the power system. The power company network was usually interspersed with insulating transformers and had most of the disadvantages of an old-fashioned rural open wire line plus the hazards of power contact, induction, rise of ground potential, etc.

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FIG 1—EIGHT-HUNDRED-MILE circuit of Southwest Power Pool leased from Bell system for dispatching and operation

Unified Communication Delayed

In 1924, there were many special problems in power system communication which had not received adequate attention. Carbon block detectors, fuses and heat coils protecting telephones in power stations and substations operated all too frequently, interrupting service and sometimes not preventing damage to equipment and shock or hazard to the telephone user. Telephone company representatives often had difficulty in meeting requests from power company engineers for special services because of the limitations of then existing telephone plant. The commercial policies of the telephone company were also built primarily around the needs of residence and commercial customers other than public utilities and were not readily adaptable to the latter. This led to an independent attitude on the part of many power system engineers, and helped to delay for many years the establishment of a unified coordinated communication system within each power company.

The early development of power line carrier was slowed up to some extent by its friends as well as its competitors. The manufacturers' carrier engineers in that period seemed intent on "starting from scratch" and working entirely independently of engineers who had previously carried out successful development of broadcast transmitters, broadcast receivers, marine radio, military radio, and amateur equipment.

Developments Accelerated

In spite of technical problems and commercial obstacles, every year some outstanding improvements were made in power line carrier and equipment and channels soon began to have fair reliability and predictable performance. Among the improvements between the period 1924 and 1928 were the following: 20-cycle ringing, 60-cycle ringing, voice frequency ringing, selective dial calling (1925), portable receivers and transmitters (for line crews) (1930), rack mounting, two-wire extensions, 120 v d-c tubes, pentode tubes and manual simplexing. The four out-standing improvements were capacitor coupling (1924), resonant traps, double frequency tuning, and voice-operating relays (1930). This stage of the development brings us to about 1930, and sets the stage for the use of carrier current communication channels and equipment for carrier relaying, telemetering, remote tripping and automatic load control.

Cooperation Initiated

Beginning about 1928, a few live-wire individuals in the commercial communication companies and the power companies took a real interest in power system communication problems, and decided that the communication problems of a power system were communication problems and not power problems. Among the first developments were the following: Improved schedules of rates for leased service, a special power system service contract modeled after the railroad agreements, and a special dispatching turret (with provision for common battery, dial, toll, magneto and operator's connections) with automatic ringing and complete supervision on answering, hang-up, ring-off and busy conditions (1933). Emergency handling was set up for calls where serious failure in utility or other essential public services was indicated.

Telephone Technology

In the meantime, the telephone companies system made many technical improvements in their facilities applicable to power system communication problems. More general use was made of repeaters, toll terminals, re-routing schedules for leased service, ringing relays, (replacing bells), 135-cycle ringing, 1000-cycle ringing, station storage battery supply for transmitters and relays, etc.

Communication and Telemetering

Reasons for Use

- Saving of labor in substations and power stations
- Saving of labor in dispatching office
- Saving of labor in maintenance crews
- Reduced interruptions
- Better voltage
- Promotion of public safety
- Facility in locating trouble
- Better preparations for emergencies
- Necessity with automatic load control
- Better relations with interconnected utilities
- Saving in purchased capacity and/or energy
- Saving in hydro capacity and/or energy
- Saving in steam capacity and/or energy
- Availability of graphic record
- Availability of totalizing for all interconnections
- Availability of totalizing for system load
- Facility in sharing regulation between plants

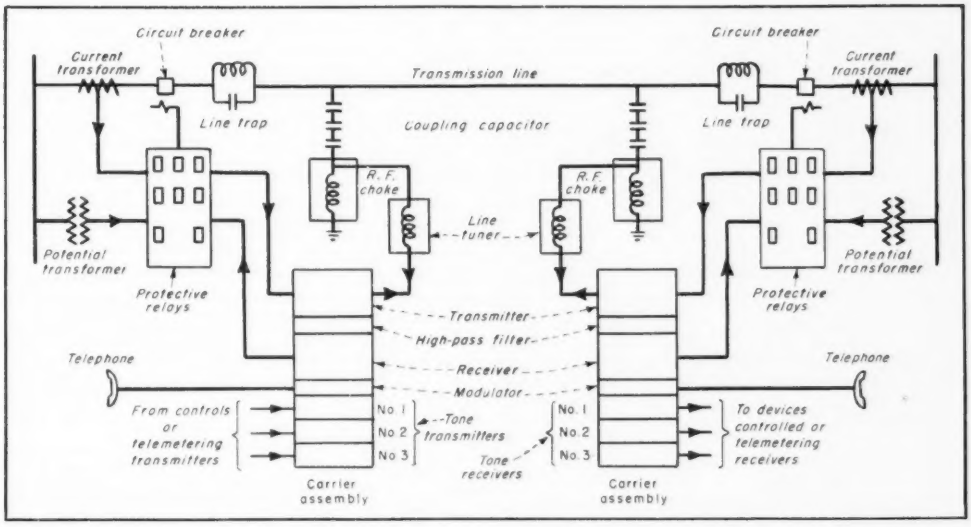

FIG 2—SCHEMATIC DIAGRAM of a typical carrier current system such as is commonly used on many modern systems

The neutralizing transformer was first used in 1935 for neutralizing rise of ground potential at power stations and substations. This application rendered insulating transformers almost obsolete, and permitted the use of leased service for a variety of new applications requiring a continuous metallic circuit. For the first time, power company substations and power stations were more generally able to use common battery or dial telephone service, telemetering, remote tripping, supervisory control, pilot wire relaying, etc., with minimum risk of interruption.

Type H Carrier

One of the major developments was the type H carrier system which could be applied to a power company owned telephone line on power line right-of-way. This provided at nominal expense an additional channel of high quality and excellent reliability, even when superimposed on a low-grade open wire line. The Bell system and other commercial communication companies in the telephone and telegraph field made many other technical improvements in the equipment in the period between 1930 and 1940. Perhaps the outstanding contribution of the Bell system was the fundamental plan of a unified coordinated communication network, suitable for a power company covering many hundreds of square miles, or even a group of companies.

Concentric Cable

In the period following 1940, several important improvements were made in carrier current facilities. In 1941, concentric cable was utilized for terminal connections. With the tuning and matching equipment placed close to the coupling capacitor, it was found practicable to convey carrier signals over concentric cable with very little loss to receiving and transmitting equipment which may be placed at any convenient location in either the substation or the power station.

In 1942 equipment developments and operating requirements widened out the carrier spectrum from 50-150 kc to about 30-250 kc. About a year later, modern

Communication and Telemetering

Reasons for Selecting Type of Channel and Equipment

- Initial cost
- Rental cost
- Maintenance and operating cost
- Life of equipment
- Salvage value
- Battery supply at terminals
- Coordination with automatic load control
- Coordination with interconnected utilities
- Distance between transmitter and receiver
- Impedance of available channels
- Accuracy requirements
- Quality
- Speed of response
- Conservation of channels or spectrum
- Availability of reserve channel
- Self calibrating or not
- Protection from channel failure
- Self resetting after channel interruption
- Indication during channel interruption
- Immunity to variations in series impedance of channel
- Immunity to variations in shunt impedance of channel
- Immunity to noise and interference
- Freedom from causing noise and interference
- Need of graphic record at receiver
- Need of totalizing at transmitter and/or receiver
- Protection from rise of ground potential
- Protection from induced voltage
- Protection from lightning
- Protection from foreign circuit contact

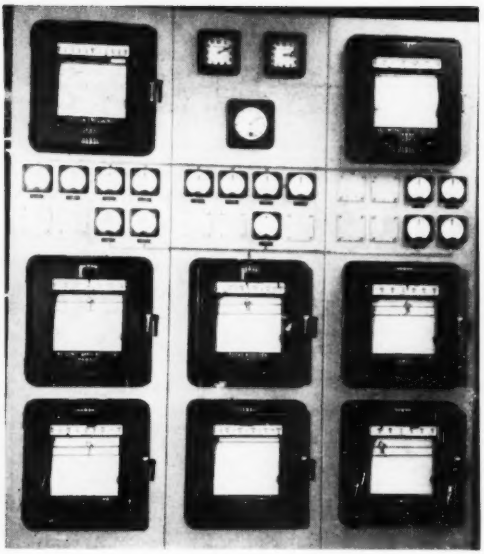

FIG 3—TYPICAL DISPATCHER'S summary panel charts show system frequency and voltage (top), net tie loads (right and left) total pool generation and total pool load (center)

power line carrier using either frequency modulation or the single side band system became popular because of reduced interference and noise.

Radio Communication

Radio communication had been utilized to a limited extent by less than a dozen power systems ever since 1919. The first installations were point-to-point radio telephone equipments. About 1933, radio telephone communication was found practicable and was used in a few situations for emergency communication. Largely due to FCC regulations, no outstanding progress was made in the use of radio telephone communication by power companies until extensive developments took place in the field of mobile radio, primarily for police work between 1935 and 1940, but including some installations by telephone companies for the utilities. This was followed by quantity production of mobile radio equipment for military uses.

The conclusion of World War II initiated the general use of space radio by electric power systems all over the country under more liberal FCC regulations. At the same time, the commercial communication companies established the general use of space radio for automobiles and trucks, both for connection with the commercial telephone network and for use as private mobile systems. This activity on the part of the telephone companies permitted a desirable unification of power system communication and gave assurance of continued technical progress, but it was found by some power companies that the general mobile type of radio service did not provide the priority essential for emergency calls of frequent occurrence on a power system, and it did not provide sufficient facilities to handle the enormous peak of traffic which occurs if a serious emergency on the power systems upsets the normal routine of life in a busy community. This situation resulted in more appreciation of the private line type of private mobile radio service. Many such installations are in service or under way and others are awaiting frequency assignments.

Frequency Allocations

The problems relating to frequency assignment and other problems of space radio are serious, but no more difficult than many of the technical and commercial problems solved in earlier years. Regardless of the ownership of the facilities, the use of both point-to-point and mobile space radio for power system communication has had an amazing growth in the last five years and will soon be as widespread in extent and at least equal in importance with metallic and carrier channels.

Telemetering

In 1924, telemetering had just been put into commercial use in a few large metropolitan systems. These installations were of the voltage balance type and utilized a metallic circuit. Many other varieties of telemetering and selsyn indication were developed and used to some extent in the period between 1924 and 1935.

None of the metallic channel telemetering facilities fully met the needs of the transmission power com-

Status in 1924 and 1949
Communication

1924	Feature	1949
Metallic Carrier	Channels	Metallic Carrier Radio
40	Carrier sets	8,000
20±	Radio stations	1,500±
0	Mobile units	17,000
3 mc	Max frequency	960 mc
AM	Modulation	AM FM SS Pulse Code Pulse Time
0.1%	Frequency stability	0.001%
"Whoop and holler"	Quality	Toll grade

± = Approximately

Status in 1924 and 1949
Telemetering

1924	Feature	1949
Metallic	Channels	Metallic Carrier Radio
0	Maximum frequency	460 mc
0	Maximum frequency	20 kc
10 miles	Maximum distance	350 miles
5 kc	Min frequency separation	0.05%
5%	Min frequency shift	0.06%

FUTURE TRENDS

Communication

- Periodic Resurveys
- Coordination of leased and owned facilities
- Interconnection of leased and owned facilities
- Interconnection of land line, carrier and radio facilities
- Increase use of carrier on owned and leased telephone lines
- Increased reliability
- Increased channel sharing
- Better test equipment and methods
- General use of traps to provide clear channels
- Better carrier repeaters
- Lower cost equipment
- Wider spectrum for carrier
- Coordination within spectrum

Telemetering

- Universal application on interconnections
- Universal application on generating plants
- Increased reliability
- Better test equipment and methods
- More direct coupling to automatic load control and automatic combustion control
- Higher speed response
- Narrower spectrum requirements
- Increased channel sharing
- Extension to space radio
- Exploration of 12,700-mc band
- Micro wave channels
- Pulse modulation

panies with their greater distances and more remote points to be served.

Torque Balance

In 1932, the torque balance system of telemetering was developed and proved to be one of the most useful of the schemes thus far available. The application of telemetering to carrier systems developed very slowly in the early 1930's, and much of the development work was done by the engineers of the power companies. Commercial application started about 1935. Even as late as 1942, most of the recognized schemes of carrier telemetering involved the equipment of at least two manufacturers. Sometimes as many as four manufacturers were involved. Nevertheless, the several different schemes of carrier telemetering operated very satisfactorily and came into very extensive use in the period following 1940. Most of these systems were of the high rate impulse type. Various improvements in relays, condensers, feed-back circuits and watt-hour meter accessories contributed greatly to increased reliability.

Crowded Spectrum

Crystal control of oscillator frequency was almost ideally suited to carrier telemetering installations, and became very popular following its introduction about 1940. After 1940, the increasing use of carrier current channels crowded the carrier spectrum and put a premium on facilities using a single frequency and a very narrow band width. Crystal control met this need. In 1943, commercial application was made of the principle of using several distinct audio tones to modulate the carrier frequency and thus make one carrier frequency do the work of several.

Very recently, certain manufacturers have developed carrier systems involving continuous indication of telemeter quantities, thus obviating the delay of several seconds inherent in integrating or storage type of receiving circuits. This delay was a major disadvantage to the impulse schemes, but in the period between 1935 and 1942, time delays were reduced from 20 or 30 sec. to 5 sec. or less. Since such delays cascade in telemetering, load totalizing, automatic load control, governor operation, and combustion control, it is desirable to make every one of these controls as nearly instantaneous as possible. The limit of distance of telemetering under present-day conditions is simply the limit of the carrier channel. Since telemetering impulses are easily adaptable to either carrier frequency or voice frequency repeater operation, there is no apparent limit to the distance over which telemetering can be accomplished.

Frequency Modulation

About 1944, frequency modulation systems were developed for power line carrier application. This caused renewed interest and development of an earlier principle that had been tried out for carrier telemetering. This earlier scheme (first used commercially about 1939), consisted of varying carrier frequency proportionally to the quantity to be transmitted. It was, in effect, a frequency modulation system, but would have been called a heterodyne system in those days. The outstanding difficulty with this system was the lack of carrier frequency stability and lack of synchronism between the transmitter and receiver. The application of crystal control to oscillator frequency about 1940 eliminated this difficulty. Frequency modulation is one of the few electronic principles suitable for instantaneous telemetering.

At the present time, several distinct types of telemetering are commercially available, are generally used, and are highly successful. Short distance telemetering is usually over metallic channels, and longer distance telemetering is over carrier channels.

Higher Frequencies Forecast

Although the original carrier spectrum of 50 to 150 kc was informally widened in 1942 to about 30-250 kc, the congestion is increasing and it is necessary to approximately favor those applications which help to solve this problem. Throughout the entire period of development and expansion, the utilities have recognized and solved their problems of coordination—both within the power field and with other essential services.

A new type of channel is now being developed largely as a result of research during and after World War II. Many military projects involved radio transmission of pulse signals and of metered quantities by space radio. Active development work is being carried on today, and it is probable that point-to-point radio will be utilized extensively to reduce or prevent further congestion of the present carrier spectrum. The number of available radio channels increases logarithmically with frequency, and frequencies up to 15,000 megacycles are being considered for future use.

System Voltage Regulation

Transition from short-range low-voltage to wide-area multi-voltage systems
Regulation at generating and transformation points. The flicker problem
Networks, capacitors and banking. Tap-changing under load. Feeder regulation

PRESENT PRACTICES in connection with voltage regulation on electric utility systems are the result of gradual evolution brought about by many factors incidental to the growth and development of the industry. Fundamentally, the voltage maintained by the utility at the consumers' services must be held within the limits for which the consumers' equipment is designed; otherwise difficulty may be encountered in operation of the equipment. At the same time, the voltage on the system electrically removed from the consumers' services must be regulated within other limits to insure the proper division or reactive loading between plants and interconnected lines and systems. Because of these considerations, voltage control and regulation has become a major consideration in system planning and design.

Economic Balance

It was evident from the early years of the industry that voltage control cost money, and that the narrower the limits of system voltage regulation required, the more the cost. It soon appeared that the cost of a given amount of regulation varied with the method used and the amount of load regulated per unit of equipment. For example, equipment for individual voltage regulation on ten distribution circuits is less economical than one unit of equipment regulating the bus supplying these circuits within similar limits.

The voltage ranges now accepted by the manufacturers and electric utilities for various types of consumer utilization equipment have been influenced by the fact that it is more costly to design a distribution system for narrow voltage limits, as well as by the fact that it is more costly for the manufacturer to build utilization equipment which will operate satisfactorily over wide voltage limits. The consumer pays for both so the best answer to the question of proper service voltage range is the one which results in the lowest overall cost, taking into account electric rates and cost of utilization equipment. The utility practices of today have been largely determined by these factors.

The increase in transmission voltages was very rapid after 1905, each two years or so seeing a new high. Transmission voltages advances from 13.2 kv to 16.5 kv, 22 kv, 33 kv, 40 kv, 60 kv, 66 kv, 70 kv, 88 kv, and, with a slight pause to introduce suspension insulator construction, to 110 kv, 140 kv, and 150 kv. Until these higher voltages were reached and corona became a problem, there was little change in conductor size, which was seldom larger than No. 0 copper or its equivalent. Accordingly, economical loading of lines having relatively low reactance-to-resistance rato produced voltage regulation problems of an intermediate degree.

Around 1915 there began a rapid increase in size of transmission conductors, partly because of corona limitations and partly to reduce copper losses. Improved insulators and line designs were needed and provided. The development of system voltage regulation methods became necessary to take full advantage of the larger conductor sizes. With larger amounts of power transmitted over circuits of about the same reactance as before, the voltage drops resulted in more serious problems. These problems were a challenge to utility and manufacturer engineers and both have had a part in their solution.

Philosophy of Design

In general, the major problem of system regulation has to be considered on a system-wide basis, from the desired voltage range at the consumers' services, through the distribution and sub-transmission system, and the main transmission system, to the generators. Each step along the progression can introduce voltage limitations as a result of the operating requirements of a specific part of the system. Such an approach insures a logical consideration of each phase of the voltage regulation problem and its integration into a unified and coordinated system design.

The problem in its simple form may be illustrated by

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the voltage profile of a utility system as shown in Fig 1. The magnitude of the voltage corrections required because of the load cycle of the system is evident.

Focus of Control

Economic studies have shown that, as much as possible, the voltage control requirements of a system should be provided for at the generating station, consistent with generating plant auxiliary and transmission system voltage limitations. Likewise, additional voltage regulation at the transmission substation has generally proven more economical than if it were provided at the distribution substations in that load area. In turn, regulation of the distribution substation bus has been more economical than individual feeder regulation, where field conditions have been favorable.

The extent to which over-all voltage control may be applied to a power system depends largely on the type of system. For example, where systems consisted of a number of generating stations in metropolitan areas with light interconnections between plants, it was often possible to supply considerable load voltage regulation at each plant and to that extent eliminate regulating capacity on individual circuits or substation buses which would otherwise have been required.

Interconnection

The interconnection of power systems extended the voltage regulating problem into adjacent systems because of the need for controlling reactive interchange. The greater the number of interconnections, the more complex the problem becomes. If tap-changing under-load transformers are introduced in the tie lines to adjust voltage differences between systems, the power interchange may be limited by the capacity of such equipment. These power limitations are undesirable during unforeseen outages of generating capacity when the required loading on interconnections may be several times normal. However, interconnected operation without the flexibility afforded by voltage regulating equipment imposes restrictions on the principle of bulk regulation at transmission voltages. This may result in offsetting some of the economies of power systems interconnections with an increased cost of regulating equipment at lower voltages.

Regulators Omitted

On the other hand, it is interesting to note that an adequate service voltage has been achieved on a major power system, with interconnections to adjacent systems and serving many small load centers distributed over a large area, without a multiplicity of low voltage regulators. By careful engineering, voltage regulation has been provided on an over-all basis to the extent that practically all feeder voltage regulators have been eliminated.

The Flicker Problem

Twenty five years ago, voltage flicker problems were generally not too serious. More recently, this has become increasingly severe because of the attractive manufacturing economies inherent in the use of large welders

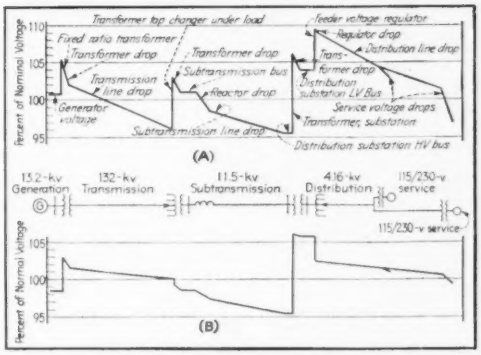


FIG 1—VOLTAGE PROFILES of typical power systems as determined by heavy load (A) or light load (B)

and the increasing use of arc furnaces for melting and refining steel. Progress in arc furnace design and the demonstrated economies of their operation have led to larger and larger furnaces with correspondingly larger service requirements. Because of the extreme fluctuations of such loads during the melt-down periods, the resulting system voltage regulating problems have become increasingly severe.

To date these flicker problems have three general solutions. One is to limit the installation of such loads to points on the transmission system where the amount of the fluctuation will be small enough to be within acceptable limits or to build our independent radial transmission line from such points of system concentration to the furnace loads. This means that the furnace load will experience voltage fluctuations greater than those permissible for general system loads. In general, such locations are only available in limited areas on the larger systems.

Other Flicker Solutions

The second solution is the installation of a synchronous condenser on the furnace supply bus which is connected to the power system through a reactor. This permits a sufficient furnace bus voltage fluctuation to allow the synchronous condenser to assume an appreciable part of the reactive load variations. This may be an attractive solution since the cost of the condenser may be partially offset by a reduction in energy costs because of improved power factor of the service. The third solution is the installation of series capacitors. This may prove economical if the voltage fluctuations need to be controlled beyond one point on the system. Recently, one power company has pioneered in the application of a 10,000-kva series capacitor for this purpose. Series capacitors have the effect of reducing the electrical length of a transmission circuit which supplies a furnace from some point on the power system of sufficient electrical stiffness to serve the swinging load. While the capacitors have no influence on the voltage fluctuations of other loads supplied from this point of system concentration, they do reduce the total voltage fluctuations at the furnace ends of the

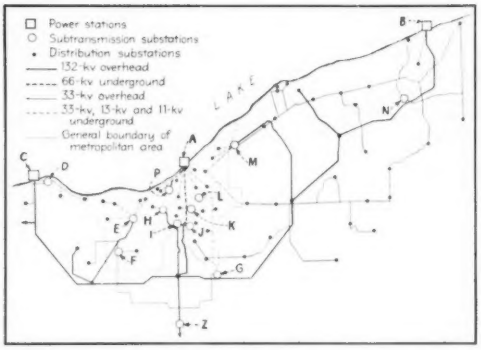


FIG 2—POINTS of voltage regulation on typical power systems

radial line and may thus permit the supplying of other loads from this same line.

Many studies have been made to evaluate the effect of voltage fluctuations on sources of illumination. Shown in Fig 3 is one correlation of perceptible voltage flicker with its rate of recurrence.

Voltage Regulation at Generating Stations

Generator voltage was originally controlled by hand adjustment of the field rheostat. The first widely used automatic voltage regulator was the Tirrill vibrating relay, introduced around 1900. The rheostatic type of regulator appearing some years later superseded the vibrating relay. Recent years have seen the development of several types of rotating regulators as well as electronic devices for the control of generator voltages.

While the control of generator voltage, to compensate for the voltage drop of the system load, is desirable within the limits of the interconnected plant and system transmission requirements, the necessary incremental changes required for this purpose are generally rather infrequent. Scheduled variations which may occur in the generating station during bus voltage normal system operations are usually not so great as to demand regulating equipment for station auxiliaries. On the other hand, generator voltage regulation during fault and emergency overload conditions involves another phase of the system voltage regulating problem.

Stability and Regulation

The present high loading practice on transmission systems is due in many cases to war loads being taken on in a period when material for additional lines was not available. From the standpoint of economical use of plant investment, these high loadings are desirable, and will probably be continued. As a direct consequence, the steady state and transient stability limitations become more significant in the operation of many power systems. In general, stability is closely related to the problem of system voltage regulation. Low generator reactance, parallel transmission lines, and low reactance transformers all involve a reduction in the impedance of the components of the over-all system and serve to improve system stability limits and decrease system voltage regulation at the same time.

Modern generator voltage regulators provide high speed excitation control. This has increased the stability limits of the power systems and so has been helpful in the operation of today's heavily loaded transmission circuits.

Voltage on Auxiliaries

A hardly less important purpose of automatic voltage regulation at generating stations is the maintenance of adequate voltage on the plant auxiliaries. In the case where such auxiliaries are not carried on house generators, automatic regulation is essential to avoid cascading of system trouble because of the possible loss of station capacity resulting from low auxiliary supply voltage.

Another solution to the cascading of system trouble because of low auxiliary supply voltage has been developed on one power system. This system is designed for satisfactory auxiliary operation at 70% voltage. The station auxiliary system is of the unit type utilizing induction motors throughout with properly coordinated control equipment.

Transmission Substations

In the earlier days of power transmission at generated voltage over short lines, the control of generator voltage alone was generally satisfactory. As the transmission distance increased, the voltage increased and the need for additional voltage control became evident. Around 1910 the synchronous motor was applied as a means of maintaining voltage and power factor at the receiving end of the line. At the present time, the control of voltage at transmission substations designed for sectionalizing and tap circuits can be provided with synchronous condensers or shunt capacitors. Though generally more costly, the former may be required from the system stability point of view.

Although shunt capacitors were used for voltage control about the same time as synchronous condensers, they were not widely used by the industry until relatively recently. Manufacturing economies have resulted in a general lowering of capacitor costs and their use has become quite extensive. As larger capacity switches are developed, switched capacitors will probably further supplant synchronous condensers for voltage control and power factor correction. These devices are usually applied at the terminals or other strategic points on the transmission system.

Transmission Regulation

Transmission substations which step down primary voltage for the subtransmission throughout a load area are often the logical locations of voltage regulating facilities which may provide the amount of general voltage regulation required. Such facilities may not only be tailored to the requirements of the service area, but may free the generating stations from the necessity of maintaining suitable service voltage at these locations, and thus release the voltage regulating capacity of the generators for use in the specific service area in which the plant is located, or for controlling the reactive

flow over all portions of the transmission system.

Synchronous condensers were used in early transmission substations for this purpose, and where conditions are suitable and the reactive generating capacity of the condenser is needed, such installations may still prove economical. In the period from 1920 to 1925, an increasing need developed for a more economical and flexible solution than the synchronous condenser offered for the voltage regulating problem at transmission substations. In response to this need, equipment was developed with which it was possible to change the voltage ratio of transformers without removing load from the transformer. At first this equipment was large and cumbersome, and required a considerable amount of maintenance. However, by the end of the Twenties, apparatus for reliable tap-changing under load was generally available for larger transformers.

Tap-changing Under Load

This equipment has become a most useful tool in the hands of the system designer. Commonly designated as TCUL transformers, this equipment allows subtransmission load area voltage requirements to be provided locally to a greater extent than the synchronous condenser permitted. Transformers of this type also provide for the flexible interconnection of plants and the proper regulation of reactive interchange on such interconnections, and at the same time permit individual plants to regulate voltage for service in their own load areas.

A little later, the same basic type of equipment was modified so that the phase angle could be shifted. While this modification is not used as commonly as the voltage ratio, tap-changing-under-load transformers, it has proved extremely useful in the solution of many specific problems involving the control of the flow of power over various parallel system interconnections.

Distribution System

During the Twenties when the load was growing rapidly the large distribution substation was generally the rule. Individual feeder regulators were the most economical means of controlling the distribution voltage. The greater part of the distribution class of power in the United States is probably served through substations of this type.

However, within the last 15 years the smaller substation has become increasingly more common, due largely by the development of the smaller TCUL transformer and the factory built unit substation. This combination has enabled the system designer to add facilities at the time and place the load occurs and thus minimize dependence upon long range forecasting.

By gradual evolution the original hand-operated feeder voltage regulator of 1900 developed into the precise automatic induction or step-type regulator of today. It was adapted for automatic operation about 1908 and became self-contained in 1930. Individual feeder regulators were predominantly of the single-phase types although three-phase types were used where circuit characteristics permitted. The use

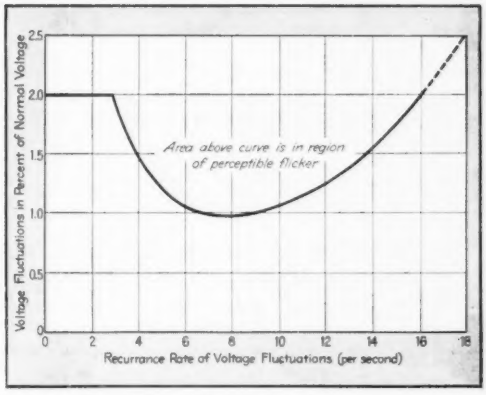


FIG 3–PERCEPTIBLE FLICKER depends on recurrance rate

of the group type of regulator for bus voltage regulation has been employed for many years for commercial and industrial type loads. At the present time group regulation on lower voltage systems in higher density areas is being employed more frequently. Shown in Fig 5 are the various current arrangements of substation voltage regulating equipment.

Feeder Regulators

Individual feeder voltage regulators were incorporated in distribution substations to correct for substation bus variation and voltage drop from the substation to the point of compensation. This is usually at or somewhat beyond the junction of the feeder proper and the mains and laterals to which the distribution transformers are connected. About 3% voltage drop in the mains and laterals is generally allowed between the first and last transformers of the circuit in urban territory. This is an important consideration in connection with the economic size of the feeder since it determines the investment in copper required.

There are a number of methods of reducing the range of voltage drop between the first and last distribution transformers. A common method is by backfeeding, that is, the first transformer is not directly connected to the feeder proper but rather to mains which have been brought back toward the substation from the termination of the feeder proper. This permits moving the point of compensation or voltage correction farther out on the circuit and so reduces the drop between the first and last transformer.

Networks and Capacitors

The primary network may also be useful for this purpose. It involves tying the ends of mains and laterals of adjacent circuits. The multiplicity of conductor paths so provided, as well as the diversity of the loads, will reduce the voltage drop to the last transformer and so permit an extension of the area served. In order to be economical, this generally requires serveral units and a substantial area.

Shunt capacitors are often used to reduce the

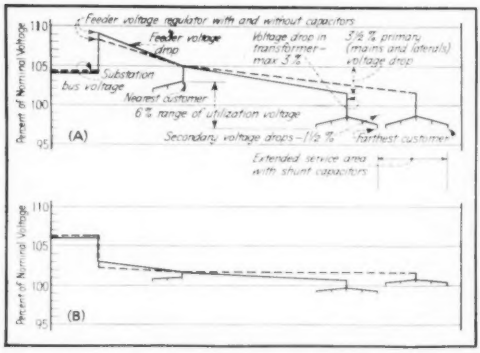


FIG 4—VOLTAGE PROFILES of a typical distribution circuit. Service areas extended (dashed lines) by application of capacitors—(A) Heavy load, without capacitors (full lines) and with capacitors at end of feeder (dashed lines); (B) Light load without capacitors (full lines) and with capacitors at end of feeder (dashed lines)

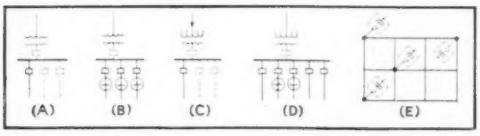


FIG 5—SUBSTATION REGULATION arrangements—(A) Unregulated bus, unregulated feeders; (B) Unregulated bus, regulated feeders; (C) Regulated bus, unregulated feeders; (D) Composite, regulated bus and feeders; (E) Unregulated low-voltage network

voltage spread between first and last transformers and are generally applied at the ends of mains and laterals. They produce a voltage rise which is an offset to the voltage drops on the circuit and release capacity all the way back to the generator through improvement in power factor.

Pole-top Regulators

Within the last fifteen years pole mounted voltage regulators have been developed, providing still another method of reducing the voltage drop to the last transformer on the circuit. The load factor of the average urban residential customer has increased over the years and the minimum loads on many feeder circuits have become as high as 30 or 40% of the maximum loads. This has pointed the way to the possibility of using fixed boost auto-transformers on the more remote mains to economically correct for this base load voltage drop.

The development of smaller TCUL transformers in the Thirties reopened the possibility of economically returning to the original practice of bus voltage regulation. Although limited in application to substations where the feeder portions of the circuits have about the same electrical length and load, usually where the area load densities are high, this practice offers substantial economies and is becoming increasingly popular.

The secondary distribution system includes the transformer, secondary main and service loop. The secondary system is usually designed on a 6% voltage drop basis with about one-half of this drop allocated to the transformer.

The sudden voltage drop imposed by motor starting currents is the usual cause of voltage flicker on secondary circuits. Generally the size of the motor which may be connected to the secondary mains is restricted. The permissible flicker voltage usually restricts the length of the secondary and determines secondary design. Shown in Fig 4 is a typical voltage profile on a distribution circuit.

Banking and Network

The secondary network shown in Fig 5 represents an ultimate in voltage uniformity and service continuity. The secondary network is used in commercial areas which generally have a high load density. The 120/208-v, 4-wire system is practically universal for secondary networks. As might be expected, improved voltage regulation as well as better flicker characteristics are among the advantages of this plan.

Example of Regulation

An example of the treatment of the voltage regulation problem of one midwestern utility is shown in Fig 2. This system, like most others, experienced the gradual development of voltage regulation practices from the early days to the present. The letters on the diagram designate key points where voltage regulation is provided:

(A) indicates a generating station located in a large local load area of some 300 Mw served at generator voltage. Since a large percentage of this load is not otherwise regulated, the station bus must be controlled to provide proper service voltage.

(B) indicates a generating station with some 100 Mw of local load served at generator voltage. This local load requires as constant a voltage as possible. Regulation of voltage for control of system reactive is limited to periods of highest system loading or emergencies.

(C) indicates a generating station with no significant local service loads; consequently voltage control may be used for necessary control of reactive loading.

(D) to (N), inclusive, indicate transmission substations provided with TCUL transformers to regulate voltage for their subtransmission systems. The load characteristics of these areas do not coincide with that at (A), which is primarily a daytime peak load. Independent voltage regulation is necessary and may be tailored to best fit the over-all regulation requirements of the specific service area.

Distribution substations, shown as solid dots, are generally provided with individual voltage regulators on each feeder but not usually with bus regulation other than that provided at the transmission substations. However, bus regulation is used in cases where general load conditions permit, as shown as (P).

(Z) indicates a normally closed interconnection provided with TCUL voltage regulation to control reactive interchange between systems.

SHREVEPORT

another city goes ALL *Federal*

Commissioner of Public Safety A. B. "Kotton" Morris (left) and Chief of Police E. G. "Ed" Huckabay making initial call over the new Federal FM 2-way mobile radiotelephone system installed at Shreveport, La.

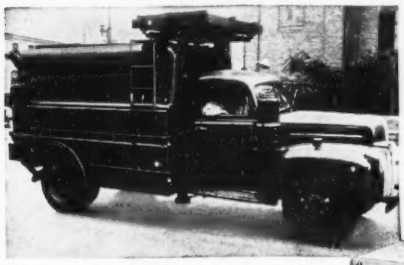
New Federal Mobile FM Radio System serves Police, Fire and Water Departments . . . another example of how a complete Federal system can provide efficient communications service for every type of operation.

Federal does it again . . . installs another comprehensive system of radio protection for an entire municipality . . . in Shreveport, La.

Federal Mobile FM Radio equipment was specified as best suited in every way to convert Shreveport's AM network to modern FM operation. The new Shreveport installation, which ranks with the finest in the country, comprises a 250-Watt Federal FM Transmitter and 40 Federal Mobile FM Transmitter-Receiver Units in fire apparatus, police cruisers, official cars, maintenance trucks and Water Department vehicles. And Federal has extended coverage to police cruisers in nearby Bossier Parish.

Fire Chief Floyd Kendrick (left) and Deputy Fire Chief H. C. Winbery make their first report through the new FM radio facilities.

The same comprehensive coverage, provided at Shreveport by Federal Mobile FM Radio equipment, is available for every type of communication need—not only for municipalities but for taxi companies, bus lines, public utilities, lumber camps, pipelines and other fleet operations. For information, write to Department I-917.



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A typical Federal Mobile Transmitter-Receiver Unit.

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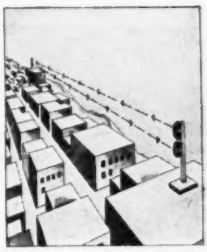

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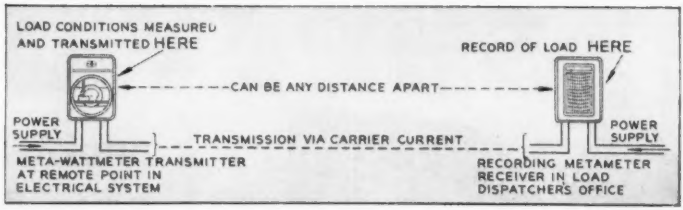
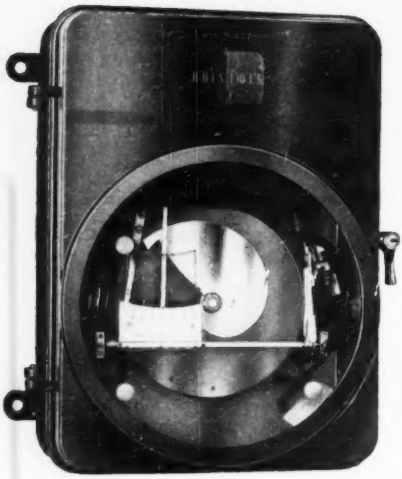
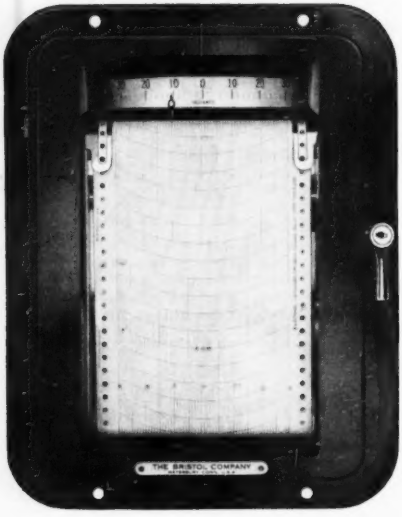
HOW TO PREDICT AND PREVENT TROUBLE FROM A DISTANCE


LOAD CONDITIONS MEASURED AND TRANSMITTED HERE
RECORD OF LOAD HERE
CAN BE ANY DISTANCE APART
POWER SUPPLY
TRANSMISSION VIA CARRIER CURRENT
POWER SUPPLY
META-WATTMETER TRANSMITTER AT REMOTE POINT IN ELECTRICAL SYSTEM
RECORDING METAMETER RECEIVER IN LOAD DISPATCHER'S OFFICE





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Among uses of the Metameter are:

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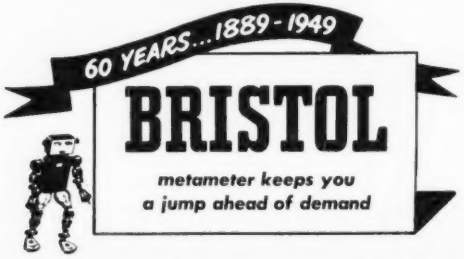
2. Output, or total generated power, of each generating station.
3. Total output of all generating stations, on a single instrument.
4. Active and reactive power and power demand at key points on important transmission circuits.
5. Water level and waterwheel gate position in hydro-electric plant.

FOR OPERATOR OF GENERATING STATION

1. Total output generated in system.
2. Output of each associated attended or unattended generating station in system.
3. Desired output of operator's own station.

FOR DISPATCHER OF DISTRIBUTION SYSTEM

1. Total kilowatt load on unattended substations.
2. Bus voltage of unattended station.
3. Feeder amperes.



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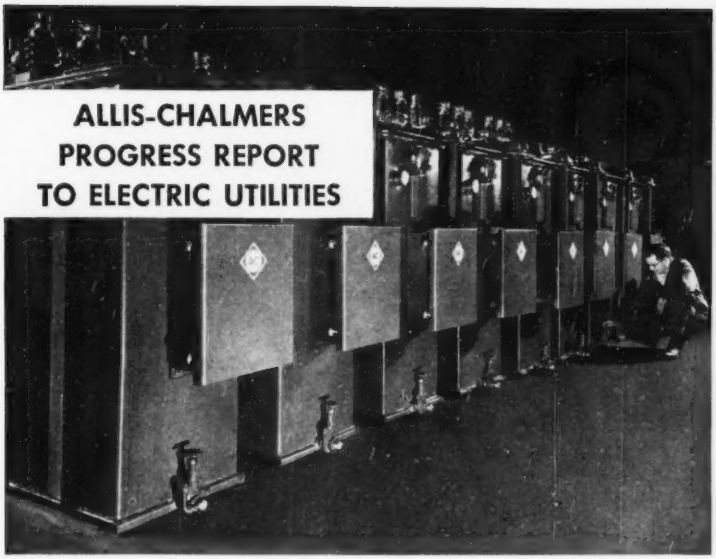
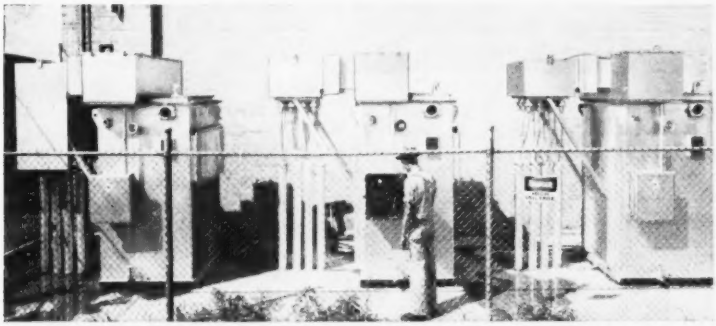
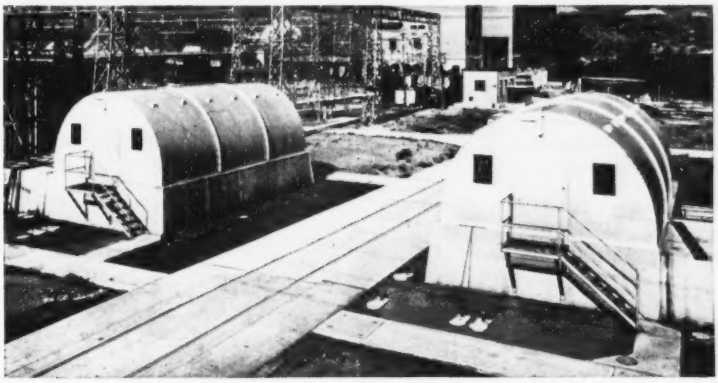


BEST DELIVERY IN INDUSTRY on single-phase regulators is result of "streamlined" production



DELIVERY UNDER 1 YEAR on three-phase regulators. Pictured, 250 kva, 4160 v, ±10% units in South



SYNCHRONOUS CONDENSERS, air or hydrogen-cooled from A-C. Pictured, two 20,000 kva units.

Production Upped 500% on 5/8% Step Feeder Voltage Regulators!

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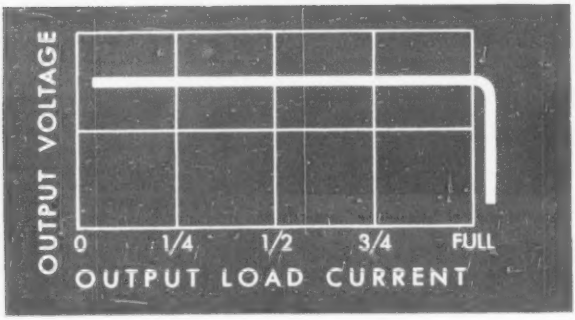

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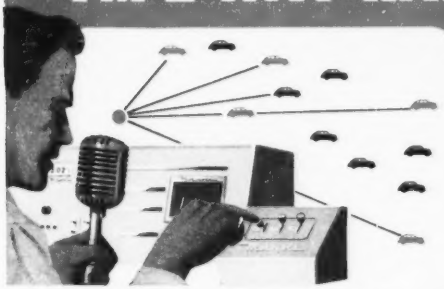

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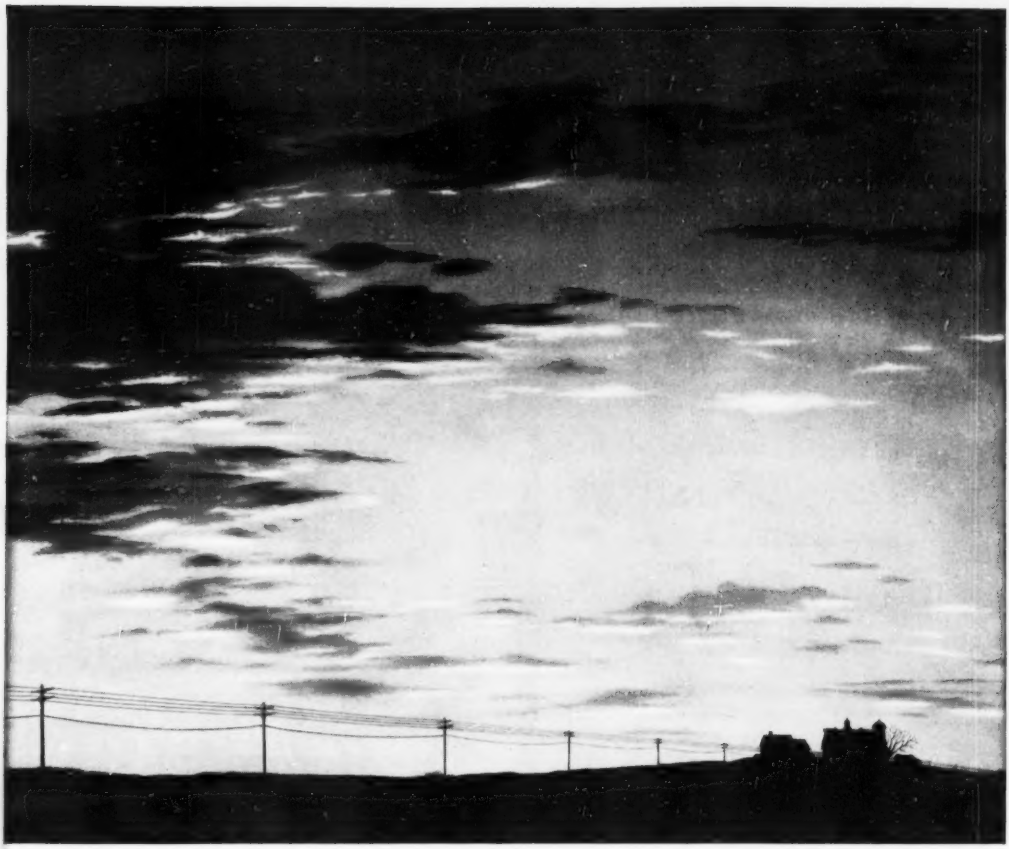

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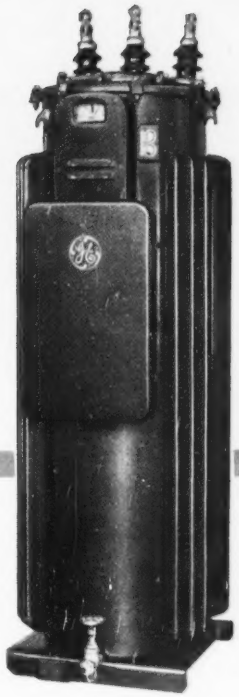

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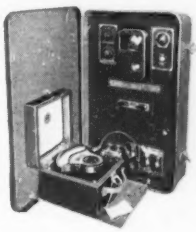
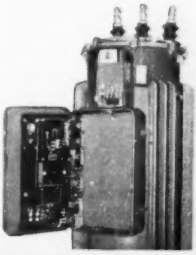


You asked for a place to put testing instrument. The new regulator has a shelf built into the control cabinet door which locks the door open, keeps it from swinging, and at the same time provides a handy place for portable instruments. Note the good appearance of the semi-flush control panel.



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(Case A)

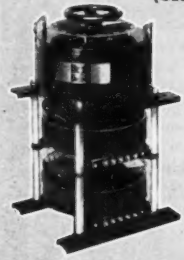
TYPE V-5
(Case A)

TYPE V-5M
(Case B)

TYPE V-10HMT
(Case C)

TYPE V-20
(Case D)

TYPE 50-B
(Case E)



TYPE 50-BG3
(Case H)

TYPE V-5G3
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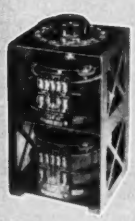

TYPE V-10G2
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TYPE V-20G3
(Case I)

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★ **OUTPUT VOLTAGES** — All single unit VARIACS are supplied with reversible, direct-reading dials showing output voltages from zero to 17% above line voltage. Both sides are calibrated for clockwise rotation; one side for dial rotation, the other for use with a pointer and panel mounting.

★ **MODERATE TEMPERATURE RISE** — Less than 50 deg. C. for continuous duty.

GENERAL SPECIFICATIONS

In the table, shown on the page at the right, the following terms apply use on 50-60 cycle input:

KVA — at *rated* line voltage only; at other output voltages, the KVA rating will be less than is shown. Any unit will handle at lower voltages a constant impedance (resistive) load which draws rated KVA at line voltage.

INPUT VOLTAGE — The voltage that should be applied to the input terminals to obtain the range of output voltages shown in the table.

OUTPUT VOLTAGE — The range of voltage obtained at the output terminals by turning the knob.

RATED AMPERES — The current that can be obtained safely at *all* positions of the dial

MAXIMUM AMPERES — The current that can be obtained safely at *rated* line voltage (115 or 230 volts) over 0 to 20 and 85-115 or 0-40 and 170-230 on the dial.

CASE — The case letter description (see illustrations) is as follows:

CASE A: Panel mounting, terminals exposed.
CASE B: Protective case around windings, terminals exposed.
CASE C: Mounted, with terminal cover, convenience outlet, switch and line cord.
CASE D: Protective case, terminal cover, BX outlets.
CASE E: Protective case around terminals, 1¼" threaded hole for pipe.
CASE F: 3-gang, top unit similar to B, others no case; 2-gang, both units inside mounting, no case around windings.
CASE G: Same as above.
CASE H: Top unit similar to E, others no case around windings.
CASE I: 3-gang, top unit similar to D, others no case but terminal cover with BX outlets; 2-gang both units inside mounting, no case but termina cover with BX outlets.

DIALS SUPPLIED — ALL VARIACS are supplied with a dial reading from 0 to 135 or 0 to 270 volts (for 115- or 230-volt input). If requested, dials reading from 0 to 115 or 0 to 230 volts will be supplied.

GENERAL RADIO COMPANY
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THIS TABLE SHOWS THE WIDE VARIETY OF VARIACS

INPUT VOLTS	OUTPUT KVA*	OUTPUT VOLTS	OUTPUT RATED AMPS.	OUTPUT MAX. AMPS.	TYPE	PRICE	CASE	DESCRIPTION
SINGLE PHASE								
115	.170	0—115 0—135	1.0	1.5	200-B	$12.50	A	Single Unit
115	.862	0—115 0—135	5.0	7.5	V-5 V-5M V-5MT	18.50 20.50 25.00	A B C	Single Unit Single Unit Single Unit
115	1.72	0—115 0—135	10.0	15.0	V-10 V-10M V-10MT	33.00 35.50 40.00	A B C	Single Unit Single Unit Single Unit
115	3.45	0—115 0—135	20.0	30.0	V-20	55.00	D	Single Unit
115	5.17	0—115 0—135	40.0	45.0	50-A	140.00	E	Single Unit
115	6.9	0—115 0—135	40.0	60.0	V-20G2	126.00	I	2-Gang. Windings in *parallel*. Requires 1 P-1 Choke—$10 additional
115	10.35	0—115 0—135	80.0	90.0	50-AG2	310.00	H	2-Gang. Windings in *parallel*. Requires 1 P-1 Choke—$10 additional
115	10.35	0—115 0—135	60.0	90.0	V-20G3	182.00	I	3-Gang. Windings in *parallel*. Requires 1 P-1 Choke ($10) and 1 P-2 Choke ($12) additional
115	15.52	0—115 0—135	120.0	135.0	50-AG3	460.00	H	3-Gang. Windings in *parallel*. Requires 1 P-1 Choke ($10) and 1 P-2 Choke ($12) additional
230	.575	0—230 0—270 (0—200) (0—270)	2.0 (1.0)	2.5 (2.5)	V-5H V-5HM V-5HMT	21.00 23.00 27.50	A B C	Single Unit Single Unit Single Unit
(115)								
230	1.15	0—230 0—270 (0—200) (0—270)	4.0 (2.0)	5.0 (5.0)	V-10H V-10HM V-10HMT	34.00 36.50 41.00	A B C	Single Unit Single Unit Single Unit
(115)								
230	1.72	0—230 0—270 (0—200) (0—270)	5.0 (2.5)	7.5 (7.5)	V-5G2	49.00	G	2-Gang. Windings in *series*. Cannot be used with grounded load
(115)								
230	2.30	0—230 0—270 (0—200) (0—270)	8.0 (4.0)	10.0 (10.0)	V-20HM	55.00	D	Single Unit
(115)								
230	3.45	0—230 0—270 (0—200) (0—270)	10.0 (5.0)	15.0 (15.0)	V-10G2	79.00	F	2-Gang. Windings in *series*. Cannot be used with grounded load
(115)								
230	4.60	0—230 0—270 (0—200) (0—270)	16.0 (8.0)	20.0 (20.0)	V-20HG2	136.00	I	2-Gang. Windings in *parallel*. Requires 1 P-1 Choke—$10 additional
(115)								
230	6.90	0—230 0—270 (0—200) (0—270)	20.0 (10.0)	30.0 (30.0)	V-20G2	126.00	I	2-Gang. Windings in *series*. Cannot be used with grounded load
(115)								
230	7.13	0—230 0—270 (0—230)	20.0 (10.0)	31.0 (31.0)	50-B	140.00	E	Single Unit
(115)								
230	14.26	0—230 0—270 (0—230)	40.0 (20.0)	62.0 (62.0)	50-BG2	310.00	H	2-Gang. Windings in *parallel*. Requires 1 P-1 Choke—$10 additional
(115)								
230	21.39	0—230 0—270 (0—230)	60.0 (30.0)	93.0 (93.0)	50-BG3	460.00	H	3-Gang. Windings in *parallel*. Requires additional 1 P-1 Choke ($10) and 1 P-2 Choke ($12)
(115)								
THREE PHASE								
115	1.5	0—115 0—135	5.0	7.5	V-5G2	49.00	G	2-Gang. Open Delta
115	3.0	0—115 0—135	10.0	15.0	V-10G2	79.00	F	2-Gang. Open Delta
115	6.0	0—115 0—135	20.0	30.0	V-20G2	126.00	I	2-Gang. Open Delta
115	9.0	0—115 0—135	40.0	45.0	50-AG2	310.00	H	2-Gang. Open Delta
230	1.0	0—230 0—270 (0—200) (0—270)	2.0 (1.0)	2.5 (2.5)	V-5HG2	54.00	G	2-Gang. Open Delta
(115)								
230	2.0	0—230 0—270 (0—200) (0—270)	4.0 (2.0)	5.0 (5.0)	V-10HG2	81.00	F	2-Gang. Open Delta
(115)								
230	3.0	0—230	5.0	7.5	V-5G3	68.50	G	3-Gang. Wye
230	4.0	0—230 0—270 (0—200) (0—270)	8.0 (4.0)	10.0 (10.0)	V-20HG2	126.00	I	2-Gang. Open Delta
(115)								
230	6.0	0—230	10.0	15.0	V-10G3	113.00	F	3-Gang. Wye
230	12.0	0—230	20.0	30.0	V-20G3	182.00	I	3-Gang. Wye
230	12.35	0—230 0—270 (0—230)	20.0 (10.0)	31.0 (31.0)	50-BG2	310.00	H	2-Gang. Open Delta
(115)								
230	18.0	0—230 0—270	40.0	45.0	50-AG3	460.00	H	3-Gang. Wye
460	2.0	0—460	2.0	2.5	V-5HG3	76.00	G	3-Gang. Wye
460	4.0	0—460	4.0	5.0	V-10HG3	116.00	F	3-Gang. Wye
460	8.0	0—460	8.0	10.0	V-20HG3	182.00	I	3-Gang. Wye
460	24.7	0—460	20.0	31.0	50-BG3	460.00	H	3-Gang. Wye

* KVA, in this column, is at *rated* line voltage. At other output voltages, the KVA rating is less than shown.

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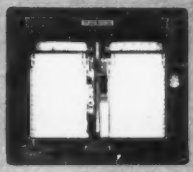

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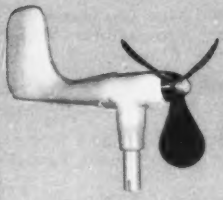

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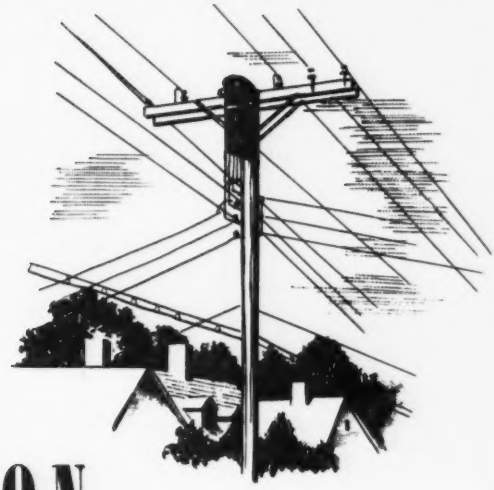


DISTRIBUTION

PROGRESS IN SUBSTATION DESIGN

DISTRIBUTION SYSTEMS

DISTRIBUTION TRANSFORMER

DISTRIBUTION RELIABILITY

Of all the components of the power system that of distribution is the most diffuse and least responsive to overall betterment. Gains made in the last quarter century have been in individual segments of the area from subtransmission to the customers' meters. Substation trend has been toward smaller average ratings with stress on both the factory assembled and utility constructed channels of standardization. Networks, more secondary than primary, and some banking have been major circuit evolutions. Changeover to four-wire and common neutral has gone along with adoption of progressively higher distribution voltages. In distribution transformers lamination stacking and cast tanks have pretty much yielded to wound cores of grain-oriented iron and welded shells. Standardization has eliminated many superfluous ratings. Reliability of the distribution system as a whole has been furthered by a gamut of devices and techniques. An interpretive survey follows.

PUSH OUT
AND FOLD

Contributors to Distribution Section

E. V. Sayles

Progress in Substation Design

Mr. Sayles is General Engineering Supervisor of Consumers Power Co, and is past Chairman of the Michigan Section, AIEE; member of the Power Transmission and Distribution Committee, AIEE; past Chairman of the Transmission and Distribution Committee, EEI; EEI Chairman of EEI-NEMA Joint Committee on Standards for Distribution Transformers; Chairman EEI-AEIC Joint Committee on Branch Circuit Protection; author of various papers on transmission and distribution subjects and substation design.

T. J. Brosnan

Distribution Systems

Mr. Brosnan, is Distribution Engineer of Buffalo Niagara Electric Corp and is chairman of the Transmission and Distribution Committee of EEI, a member of the Transmission and Distribution Committee of AIEE, the Insulated Conductor Committee of AIEE and the Cable Engineering Section of AEIC. He is a member of the joint EEI-NEMA committees on Preferred Voltages and Distribution Transformers. He has to his credit several papers on the general subject of Electric Distribution in ELECTRICAL WORLD and AIEE.

Howard P. Seelye

Distribution Transformer

Mr. Seelye is Chief Electrical Engineer, Engineering Division of The Detroit Edison Co. He is Chairman of the EEI Group of the Joint EEI-NEMA Committee on Preferred Voltage Ratings for A-C Systems and Equipment, and is a past chairman of the Transmission and Distribution Committee of EEI. He is author of the book "Electrical Distribution Engineering" and numerous articles on distribution and power system engineering subjects in AIEE, ELECTRICAL WORLD, and other publications.

Bryce Brady

Distribution Reliability

Mr. Brady is Chief Distribution Engineer of Oklahoma Gas and Electric Co and is a member of the AIEE Committee on Transmission and Distribution. He has to his credit several papers on the general subject of electric distribution in *Electrical Engineering*, ELECTRICAL WORLD, and *Electric Light and Power*.

Progress in Substation Design

Early housed substations replaced by outdoor designs, later by unitized metal-clad forms. Remote control introduced. Patterns evolved for substations at generating stations, in rural areas and for mobility in emergency

In the year of its Fiftieth Anniversary, the Electrical World commented editorially that—"The design of outdoor substations has become increasingly important because of the more extensive use of high tension lines and a consequent increase in number and in cost of substations. If good engineering has been applied to the general layout, all . . . elements in the design reduce to a problem in economics." Additional editorial comment was to the effect that ". . . A study of a number of substations on several operating properties shows wide differences of both opinions and practices."

While these quotations were made just twenty-five years ago they apply equally well to the present period. Throughout the growth of the light and power industry there have been many differences in local conditions, load densities, operating practices and engineering opinions that have had a marked effect on the transmission and distribution system. The substation appears prominently in all three major parts of the power system, namely; generation, transmission and distribution, and therefore, has received much attention.

Sound Beginning

At the close of the first fifty years of development of the light and power industry the design of substations of all classes had stabilized on a foundation of sound engineering principles. The total generating capacity installed in central stations was approximately 20,000,000 kva, or more than one-third of the present capacity. The distribution of this energy required both transmission and distribution substations and many adequate designs had already been established. This is borne out by the fact that a large number of substations constructed during this period are continuing to provide satisfactory service.

Basically, substation design constitutes the arrangement in proper electrical sequence of the equipment required to perform given functions with the proper regard for economy, safety, reliability and operating simplicity and maintenance.

Capacity Demanded

During the early part of this 25-year period there were many mergers and consolidations of smaller systems into larger integrated systems, popularly known as "super power." At the same time there was a rapid increase in the number of customers, electrification of industrial plants and the annual use per residential customer. Turbo-generators were becoming larger and the trend was toward more units installed in each generating station. This increased the problems for the substation designer and soon showed up in such ways as higher interrupting duties.

Outdoor Switchgear

By 1924 the transmission substation had become well established as an outdoor unit in the transmission system. The factor which probably contributed most to this change was the development of suitable outdoor switchgear, together with the fact that indoor buses and equipment for the higher voltages required buildings of tremendous volume. Large concentrations of power at the gateway of urban and industrial areas were becoming common and necessary to supply the increasing power demands of the period. Further, greater attention was being given to the growth of systems, and substation design was being influenced by the probable additions of new lines and equipment to be required for future expansion.

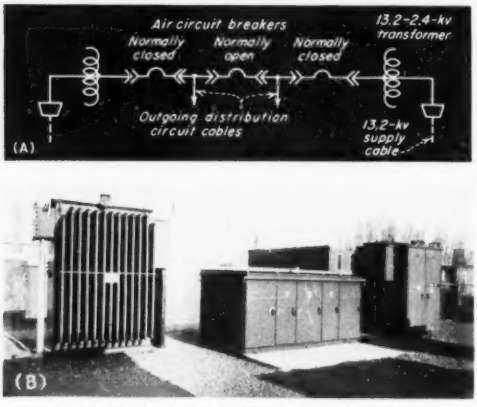
Buses and Breakers

No particular over-all pattern of substation design seemed to be favored, although duplicate buses or ring buses were inherent in most designs with the main and transfer bus being common for voltages below 100 kv. Duplicate oil circuit breakers were used for important line connections, but many designs employed single circuit breakers and transfer disconnecting switches with a bus tie circuit breaker available during times of inspection or repair.

Outdoor substation design, in large measure, centers

Prepared by E. V. SAYLES, *General Engineering Supervisor, Consumers Power Co*
with the collaboration of L. R. Gaty, Manager, Engineering Dept, Philadelphia Electric Co, J. B. Hodtum, Central Station Engineer, Allis-Chalmers Mfg Co

THE BRICK BUILDING at the left contains circuit breakers for the distribution circuits. The individual feeder regulators are arranged in two rows, one next to the building and the other in about the center of the photograph. On the right are the transformers stepping down from the supply voltage to the distribution voltage and the structure for the high voltage supply lines



A TYPICAL DUPLEX SUBSTATION with three circuit breakers (A) in the metal housing between the two transformers. In some cases the transformers are mounted closer to the switchgear with overhead metal enclosed leads connecting the transformer to the switchgear. (B) This particular installation is supplied by 13.2-kv underground cables (shown at the left of the left hand transformer) and the distribution voltage is 2.4 kv

around the type and arrangement of high voltage buses which, in turn, are influenced by the size of the substation and space available for it. Early designs usually employed strain buses with suspension insulators arranged in vertical or horizontal configuration with midspan taps. In the case of duplicate buses—unless unusually wide separation is maintained—there is always the possibility of a flashover on one bus also involving the other bus or adjacent connections. For this reason, isolation of buses by means of wider separation or with grounded steel barriers or gratings is current practice, the choice depending largely upon the station voltages and other factors.

Flat Bus

For voltages above 100 kv, the flat type of bus is used extensively where space will permit. With this construction the buses are mounted on pedestals relatively close to the ground and are of the rigid type using either copper or aluminum tubing of a size adequate for long spans. Separation of duplicate buses is limited only by the space available and complete isolation for inspection is assured. Taps and connections are readily accessible.

Insulation Levels

Perhaps one of the most important developments which has made substation design easier is the establishment of basic insulation levels for all voltage classes of substation equipment. Voltage ratings and dimensions of bus supports, disconnecting switches and the like meant very little and varied widely in early designs. The selection of this equipment some twenty-five years ago was based upon flashover values at normal frequencies. Differences in the opinions of designers regarding operating requirements and voltage ratings, which were assigned to equipment, often resulted in wide variations of insulation strength between the various elements in the substation and greatly increased construction costs.

The importance of insulation strength from an impulse voltage standpoint became evident as more knowledge was acquired regarding the magnitudes of lightning voltages and their effect upon insulation. By the establishment of standard basic insulation levels for all types of insulation, proper coordination of equipment with surge protective devices has been accomplished and greater reliability of service has been provided with more economical use of materials. Shield wires above the station have been effective in reducing damage from direct lightning strokes and form an important part in the evolution of the insulation coordination plan.

Disconnect Switches

Improvements in the design and application of disconnecting switches have had much to do with outdoor substation design in the last two decades. Early disconnecting switches were usually of the single pole hook-stick operated type. Their location, usually high in the structure, had to be selected with considerable care in order that they could be operated safely. In many cases this meant wider and lower structures and, more likely, disconnects could be operated only with greatest difficulty.

New types of gang operated switches with improved contacts and operating mechanisms have permitted much greater latitude in substation design and far greater safety in operation. Further, switches can be locked securely or interlocked with equipment to prevent faulty operation. Auxiliary control switches can also be added to remotely indicate open or closed switch position.

Motor operated disconnecting or transfer switches have further simplified substation operation and, in many cases, have made possible the elimination of circuit breakers. Using motor operated selector switches in connection with a duplicate bus and bus tie breaker, a single breaker, controlled from the central switchboard, can be readily connected to either bus.

Flashover Barriers

In recent years there has been a growing tendency, especially with the lower transmission voltages, to provide screens or barriers in outdoor stations to prevent flashover between buses and to protect operating and maintenance personnel. In effect, this type of construction is an approach to metal-clad switch gear, the bus being party enclosed—or completely enclosed in some cases. The principal difference is that the insulating medium is air and full phase-to-ground clearances are maintained.

Metal-clad switch gear for high voltage outdoor substation construction made its appearance at about the beginning of this period but has been since used to only a limited extent and for voltages well below 100 kv.

Equipment Cooling

Water-cooled transformers and regulators have largely been superseded by the use of self-cooled

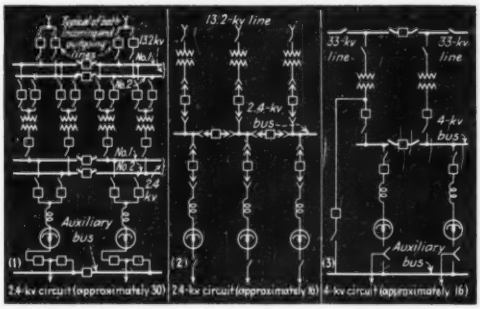
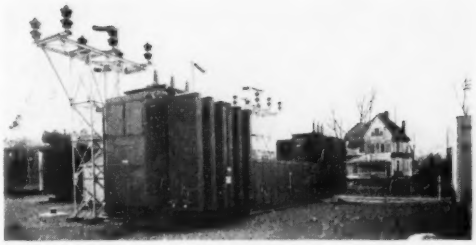


FIG 1—TYPICAL double bus arrangement for an urban distribution substation supplied at 13.2 kv. This is one of the arrangements in vogue in the early 1920's. Each transformer bank is connected to only one of the two 2.4-kv buses but each circuit is connected to the two buses through oil circuit breakers. This permits flexibility in loading the transformers by selecting the bus from which the various circuits are supplied. The transfer bus permits taking the station equipment of a circuit out of service while the load is being carried through the regulators of another circuit. Outgoing lines are frequently supplied from the 13.2-kv bus to carry local distribution loads at this voltage

FIG 2—MODERN version of an urban distribution substation supplied at 13.2 kv. The high tension switchgear has been replaced by a unit line-transformer arrangement. The transformers operate in parallel on the 2.4-kv bus which is sectionalized into a number of parts corresponding to the number of transformer banks. Each circuit is supplied by a single circuit breaker; the transfer bus has been eliminated so that to inspect and maintain the station equipment, it is necessary to do circuit switching on the highway. Since substations of this type are usually located adjacent to areas supplied by the older double bus substation, it is not necessary to provide for carrying loads at 13.2 kv from the newer substations

FIG 3—IN SUBURBAN areas, the single line arrangement shown has been used in many cases. Usually, two transformer banks are provided but in some instances there may be three or more. The distribution voltage bus is usually sectionalized into as many parts as there are transformer banks. An auxiliary bus is generally used so that the station equipment can be taken out of service for inspection and maintenance purposes. Usually, the high tension switching and transformer banks are located out of doors with the switchgear enclosed in a building. The regulators may be in the building or out-door



AN OUTDOOR 66-13.2 kv installation with the low tension circuit breakers in metal cubicles between the two transformers. A portion of the enclosure for the 13.2 kv reactors can be seen at the extreme right

AN EXAMPLE of substation architectural treatment for a substation located in a residential area

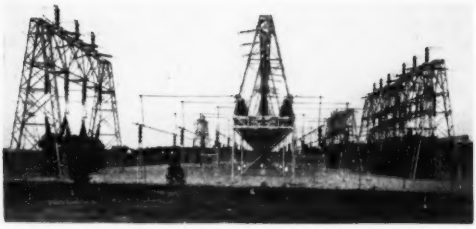
equipment. This has done much to simplify substation design by the elimination of pumps and piping. The greater size of self-cooled, forced oil-cooled, and combination types of units has been offset to some extent by the greater use of three phase units.

There have always been a few interesting variations from currently accepted designs. Recently, because of unique local conditions and problems, it was necessary to construct a completely enclosed 115-kv substation in a highly developed business area. Very special cases always require unusual designs.

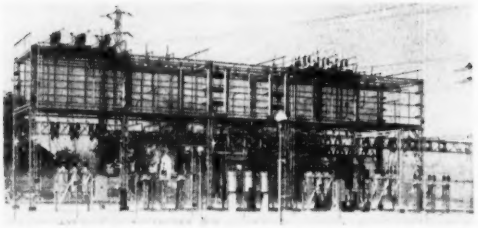
Distribution Substations

In the early years of the industry development, the distribution substation was an inherent part of the generating station. At the end of the first 50 years the distribution substation had become established as an independent unit at many locations remote from generating stations, but supplied by high voltage lines. These distribution substations in urban and suburban areas were becoming large in size and capacity to provide for present and future loads in substantial areas. This was logical due to the modest load densities which permitted satisfactory regulation of new distribution circuits. Very small substations with higher distribution voltages were required in the rural areas to supply the sparsely settled low load density territories.

Distribution voltages in common use had not reached the high level of today and were principally 2,400 v, although 4,800 and 7,200 v were on the increase. The reconnection of three-wire ungrounded circuits for four-wire Y-connected grounded operation was becoming a useful practice to economically expand systems to supply the rapidly growing areas and loads.



A 46-KV INSTALLATION using the flat type bus construction built in the early 1930's. Bus supports are mounted on steel pedestals relatively close to the ground and buses consist of aluminum tubing on long spans. The installation consists of a main and transfer bus with selector switches installed on the high central structure. Wide separation of buses shows isolation possibilities and complete accessibility of taps and connections



A MODERN TYPE of 23-kv bus structure consisting of a main and transfer bus arranged vertically in the outdoor structure with steel screens surrounding the buses on three sides to prevent flashover between buses and to facilitate maintenance. The arrangement consists of a main and transfer bus with bus tie circuit breaker. As illustrated, the structure is assembled from a few standardized lengths of prefabricated welded steel members

Indoor Stations

The large indoor distribution substations supplying the urban areas were usually in congested districts and close to the load centers of their areas. The substation building was, of necessity, very large in order to contain the number of circuits and amount of equipment planned. A great deal of attention was given to architectural treatment to fit into the existing community and to present a pleasing appearance. Residential type architecture was used in the design of many distribution substations to make them harmonize with the neighborhood. Zoning restrictions, which later became an important consideration, were generally not in existence during this early period.

During this period the building costs were reasonable and the building provided a suitable means for completely enclosing transformers, buses, circuit breakers and other equipment to reduce possible objections to noise from its operation. Two factors influenced the erection of the building of large distribution substations in the urban area; one was the difficulty of obtaining the required ground area. This also caused many designers to provide multi-story buildings in order to economize on ground space. The other factor was the economy of attending operators, since appropriate automatic equipment was not available. Therefore, the circuits from the urban substation of that day were large in number and supplied areas that today would be considered remote from the distributing point.

Sizes Decrease

Departures from the practice of building relatively large indoor substations became reasonably frequent by the mid-twenties, which also marked the beginning of a higher rate of residential load growth than had been previously experienced. This growth was both in the usage of residential customers as well as in the number of residential customers, and included the construction of new residential areas. These areas were frequently at some distance from existing substations and required the construction of new substations for the supply of exclusively residential and commercial load. These were frequently smaller in ultimate capacity as the expected load density per square mile was far lower than could be expected in urban areas.

These smaller substations continued to be of the indoor type mainly due to the lack of suitable outdoor equipment, except transformer banks and high voltage switching equipment. The development of satisfactory outdoor regulators and later of outdoor low voltage metal-clad switchgear has permitted the complete elimination of buildings in the smaller distribution substations. A building may be economically justified or may be desirable to meet zoning rules or esthetic considerations in multiple circuit substations, particularly where circuit reactors are required. The lower cost of indoor metal-clad switchgear involving a large number of items may exceed the construction cost of the enclosing building. The availability of highly reliable automatic equipment and supervisory control equipment accelerated the elimination of the building type substation.

Breakers and Regulators

Improvements in the design of the moderate capacity urban substation were aided greatly by the development of the oil-tight circuit breaker. This made the heavy type of cellular construction less necessary and the situation was further improved by the reduction in size and capacity of the distribution substation itself. Costly types of cellular construction gave way to lighter non-metallic or metal barriers and finally to the complete metallic enclosure of the breaker. This permitted much smaller structures with corresponding reductions in building sizes. Induction voltage regulators—installed on practically all distribution circuits—which had required the use of separate operating auxiliaries, were redesigned for outdoor operation and with the auxiliary equipment contained in the regulator itself. This permitted further reduction in building size by removal of the regulators to an outdoor location.

Remote Control

Switchboard and control equipment for the moderate capacity urban substation originally followed the pattern of the large substation with a central assembly of switchboard panels containing the necessary instru-

ments, relays and control equipment. However, where the large substation employed operators with manually operated controls, the smaller substation relied upon the automatic reclosing of feeder circuits in case of trouble. Remote metering and alarm for unsafe operating conditions followed naturally as suitable types of equipment were made available.

The success of this type of automatic operation soon led to other automatic features including the remote operation of the station from a central location, although the completely automatic substation—without remote control—still remains the basic type for moderate capacity and small substations. These developments greatly simplified substation design. Central switchboards with expensive conduit and control layouts were eliminated by the location of relay and control equipment on the panel front of the circuit breaker housing. Hence, still further reductions in building size were made possible.

Increasing costs of masonry buildings have resulted in the use of many steel buildings to house the remaining indoor substation equipment. In fact, steel buildings for the small substation have been used with success for a great many years, their principal merit being their low cost and ease of erection. In recent years insulated buildings are proving to be extremely satisfactory.

Metal-clad Switchgear

With the indoor portion of the distribution substation being systematically reduced in size by the removal of equipment to an outdoor location and the elimination of facilities proved to be no longer vital to operation, there remained only the low voltage switchgear to be moved outdoors. Outdoor buses for all voltages were common but the clearances required for the large outdoor bushings necessary for circuit breakers even of the distribution voltage class, make the circuit breaker large and costly when compared with corresponding indoor types. While outdoor types of circuit breakers are available and are used occasionally, modern trends in substation design have been toward the use of indoor types with suitable metal enclosures containing not only the circuit breaker but buses, auxiliary metering and control equipment as well.

From this stage of development it has been but a short step to the design of the outdoor steel-enclosed switchgear unit of a more or less standardized type. This unit contains a section of insulated bus, circuit breaker—either of the oil or oilless type—disconnecting devices, instrument transformers, relays, meters and control equipment. Designs are such that two or more can be arranged in a continuous bus unit and added to as load requirements dictate.

Unitized Substation

It is apparent that the small distribution substation has had much to do with the development of metal-clad switchgear. The simplified wiring diagram, the relatively small capacity of the substation with the low short circuit duty on equipment, the great uniformity of requirements of a circuit connection, the oil-tight circuit breaker and the oilless breaker, the development of smaller and more adequate designs of instrument transformers—these principal factors have all contributed to the design of the metal-clad substation which has been available in recent years. These now familiar types of substations, where switchgear is com-

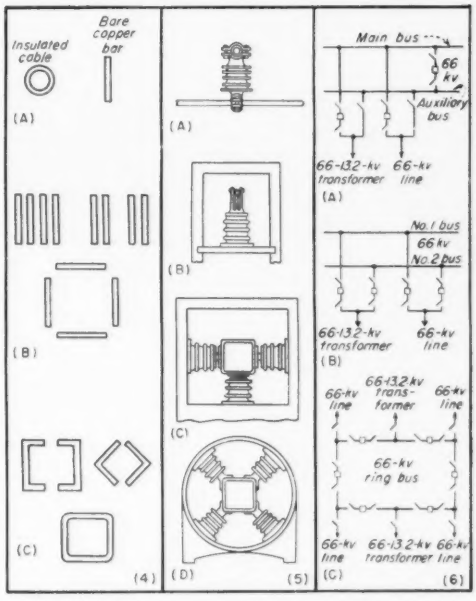
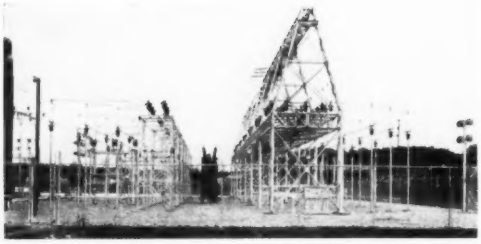


FIG 4—VARIOUS arrangements of bus conductors: (A) Earlier buses consisted of a single insulated cable or a bare copper bar, supported in either case on porcelain insulators. (B) As loads increased, additional bars were added until currents became so high that special configurations of the multiple bars were used. (C) As still higher currents (above 3,000 amp) were encountered, shapes of channels, angles, square and round tubes were used. In some cases ventilating holes are provided in the tubes

FIG 5—BUS supports: (A) For supporting single or double insulated cable buses or bare copper bars, a simple insulator was mounted on pipe frame work or on an angle iron structure. (B) To reduce the possibility of communicating faults, buses were enclosed in a concrete or other type of masonry cell with the bare copper bars supported on a post-type insulator which was bolted to the base of the cell. (C) As short circuit currents increased in magnitude, it was necessary to provide additional supports for the bus. This was frequently done by the use of two or more insulators bolted to the sides of the bus enclosure. (D) A recent development consists of three or four insulators mounted in a metal ring supporting a square or round copper tube. To enclose the conductors, split covers are bolted together between adjacent supporting rings

FIG 6—THREE types of 66-kv switching connections: (A) has been widely used for a number of years. Each circuit has one breaker connected to the main bus with a disconnecting switch connection to the auxiliary bus. An additional breaker permits supplying any line over the auxiliary bus in order to take the line breaker out of service for inspection and maintenance. (B) A typical double bus arrangement requiring two breakers per circuit. (C) is a ring type of connection using one breaker per circuit. In this type of connection a fault on any circuit requires two breakers to open. It will be noted that there is no place in the ring connection where a single fault will shut down the entire ring



A 138-KV DOUBLE BUS INSTALLATION of the early 1930's using the flat type construction. The bus insulators are mounted on steel supports relatively close to the ground and buses are of the rigid type using three-inch aluminum tubing on relatively long spans. On the center structures are mounted motor operated selector switches for transferring from one bus to another. Connections from the motor operated switch structure extend overhead right or left to separate oil circuit breaker positions, the circuit breakers being provided with special by-pass facilities. This illustrates the wide separation of buses and the complete isolation of either bus for inspection and repair. Taps and connections are readily accessible

bined with transformers and voltage regulating equipment, are available for practically all sizes, types and voltages. The fact that a substation can be built in the factory and shipped to the field completely assembled, or in major sections for field assembly, has had much to do with the popularity of this type of equipment in a period when the use and availability of skilled labor is of major importance.

The single-circuit distribution substation has been a unique development in recent years. In one form it consists of a three-phase self-cooled transformer, with low voltage taps which can be changed under load, together with a low voltage automatic reclosing circuit breaker and control equipment. This equipment is mounted on a single base as a "package" unit and can be readily installed in locations where suitable. The single circuit substation of the package type and other unit types have been exceedingly valuable in cases where small load centers have developed quickly or where industrial expansion has required the furnishing of a sizable power load to one or more customers.

Small Rurals

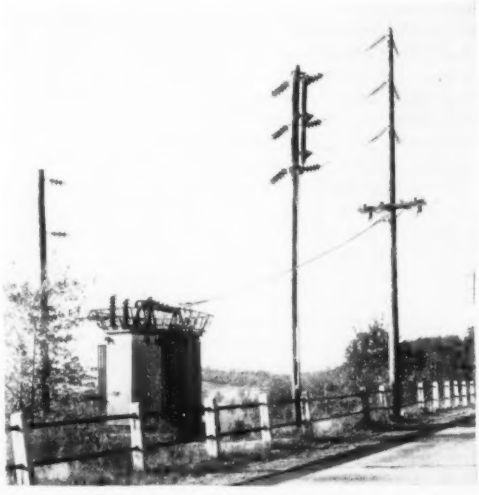
Since 1930 the tremendous expansion of rural distribution systems has done much to bring out new and simplified designs of small substations, with low cost and low maintenance being the factors which have dominated design. High voltage connections have been reduced to a load-break switch and fuses while low voltage switching often consists of repeater fuses or single pole circuit reclosers. Voltage regulating equipment is included as a part of the three phase transformer or, where it is impossible to deenergize the station for inspection, separate induction or step type regulators with by-pass facilities are provided.

For the outdoor portion of the distribution substation, structural steel in some form has always been used, although pipe framework has been used to a limited extent for certain light structures. Wood has been used to a limited degree when steel was not available and in certain severely corrosive locations. Structural steel designs have employed bolted sections, either lattice or rolled types. Recent developments indicate that there is considerable merit in using a few standardized lengths and sections of prefabricated welded steel members which can be bolted together to form whatever size and type of structure is needed. Structures of this type can be readily assembled to accommodate any wiring diagram of any voltage classification.

Bus Design

Early bus conductors consisted of single and multiple bars on supports spaced adequately to withstand the short circuit stresses which, for the large indoor buses, were substantial. Various arrangements of parallel bars were used to secure maximum current capacity and greatest resistance to mechanical stress. There followed the use of special shapes and arrangements of the bus conductors such as channels, squares and tubing—all for the purpose of increasing electrical capacity and mechanical strength. While copper conductors were always used in early designs, aluminum tubing, bars and special shapes have become common in recent years. Single point supports have always been used but ever increasing bus stresses have caused the constant development of stronger supports. As a result, special types using two or more insulator units per support have been designed. These have been a contributing factor in the development of the totally enclosed metal-clad bus which has made its appearance in recent years.

Clamp type connections for bus conductors have been universally used and have been reasonably satisfactory where high temperatures have not been present. However, there has been a recent marked trend toward



UNIT SUBSTATION erected along the route of a high voltage line to provide power for an expanding rural area

the use of soldered, brazed or welded connections for the purpose of improving current carrying capacity and insuring the permanence of the connection.

Bus Segregation

Indoor bus construction of the large substation of the 1920's was of a massive and elaborate style. Oil circuit breakers and other circuit equipment were usually installed in concrete or masonry cells with heavy masonry barriers between phases. Inasmuch as circuit breakers were subject to oil throwing during heavy circuit interruption, fire doors and oil drains were provided and every precaution taken to confine any resulting fire to a limited area. This practice frequently extended to transformers, regulators and other oil filled equipment.

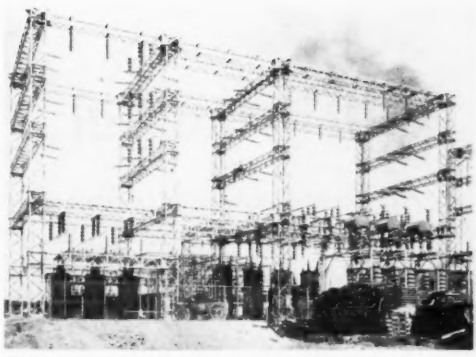
In some cases, segregation of main buses was carried to the extreme in separating the buses by an entire floor level. Much attention was also given to designs for promoting safety. Interlocking systems to avoid improper operation of disconnecting switches were included in most installations.

The design of outdoor substations at generating plants has been affected greatly by the increase in size of generating units. Often the current at generator voltage has exceeded the rating of available circuit breakers. This has resulted in a design combining the step-up transformer and generator as a unit, synchronizing and switching being done on the high voltage side. All this has tended toward the greater standardization of the outdoor switch-yard with the large step-up transformers usually close to the building and the high voltage station buses parallel to the generating plant. Segregation of large transformers by the use of metal barriers and, in so far as possible, isolation of the complete circuit from the generator terminals to the high voltage outdoor buses is being increasingly recognized as of major importance.

Fire protection for all classes of substations is receiving greater attention with adequate facilities now being considered a necessary part of the indoor station where oil filled equipment is used. Storage types of CO_2 equipment are common for indoor installations with high pressure water-fog types usually being used outdoors.

Mobile Units

During the tremendous expansion of the industry of the past decade and the building of large numbers of outdoor substations, the mobile substation has played an important role. This now familiar piece of equipment—whose design represents the maximum capacity for the minimum size and weight—has greatly influenced the design of the small outdoor substation. It has probably been the most important single factor in the elimination of spare or duplicate equipment in the substation. Designers, heretofore hesitant to rely entirely upon a single three-phase transformer, regulator or unit combination thereof, now have the assurance that, in case of failure or scheduled maintenance, the mobile unit can replace the entire substation within a reasonable time. While most mobile units are designed to substitute for the medium transmission voltage, medium capacity urban or rural distribution substation, they can also be made for railroad car mounting in large capacities and for higher voltages.



TYPICAL DESIGN of the late 1920's illustrating the use of strain buses with suspension insulators arranged in vertical configuration with mid-span taps. Illustrated is a 138-kv double bus with motor operated selector switches and one oil circuit breaker per circuit. Substation designs have been steadily improved

Possible Trends

It would seem that the past 25 years have witnessed a constant improvement in substation design with principal emphasis upon simplicity. There is every reason to believe that this will continue. Further development of the unit type distribution substation—factory built or otherwise—is certain to continue, its ultimate achievement being influenced greatly by standardization of the distribution circuit itself.

While there have been continual improvements in the design of transmission substations, they have hardly kept pace with developments and accomplishments of the smaller and lower voltage substations. Transmission substation developments now needed—and almost certain to be realized in the future— are greater standardization of the circuit connection and its auxiliary equipment. Present practices invariably contemplate individually designed structures to accommodate the original equipment and probable future additions. Minimum functional equipment such as control house, station power facilities, underground control duct system, etc, must anticipate the ultimate size of the station which frequently fails to materialize. Future designs will doubtless be more on a unit basis with each bus connection being a self-contained or packaged item consisting of structure, major equipment and control facilities all arranged to form a unit installation. Switchboard and control facilities would be an integral part of the unit, and underground ducts and manholes would be eliminated entirely. Such a concept of the transmission substation assembled from individual packaged units would result in a minimum engineering and construction effort with a substantial reduction in construction time and over-all cost.

Distribution Systems

Principles and practices of prior art extended to produce the low-voltage a.c. network, refinement of radial systems, the primary network, multi-unit substations, sectionalization, reclosure and banked secondaries

It was just about 25 years ago that the industry seemed to recognize that the distribution system, representing in most cases about one-half of the total investment in the electric service system, should receive engineering attention comparable to that provided other portions of the system.

Low-voltage A-c Networks

The first outstanding result of this engineering effort was the development of the low-voltage alternating current network distribution system for urban commercial districts. It is interesting that this development was to replace the direct current Edison system which was itself the outstanding example of system engineering in the earlier period. The Edison system had proven itself unsuited for the accommodation of the rapidly expanding commercial loads primarily because of its high cost, both in investment and operation. Other factors were the difficulty of obtaining accommodations for conversion equipment, the congestion created by the concentrations of large cables in the underground system and the growing need for alternating current supply for certain types of utilization equipment.

The low voltage alternating current network system was developed for electric distribution in those areas where maximum service reliability is important. This system has been described in papers before the American Institute of Electrical Engineers and in articles in ELECTRICAL WORLD. The essential features will be reviewed here briefly because much of the basic engineering thinking that went into the development of that system has influenced the subsequent design of the general distribution system in residential and suburban sections.

Four-wire Grid

Fig 1 is a single line diagram showing the essential features of a low-voltage alternating current network. The low-voltage system is a combined light and power grid which is star-connected, 3-phase, 4-wire and is usually operated at 120/208 v. This secondary grid is supplied by "network vaults" so located that they provide adequate supply capacity and maintain proper service voltage throughout the secondary grid under normal operating conditions and also when any one of the high voltage circuits supplying the system is out of service. Several network vaults are connected to each high voltage circuit supplying the network. Each vault is really a small automatic substation, consisting essentially of a transformer bank and a network protector connecting this transformer bank to the secondary grid. The network protector functions automatically to isolate its transformer from the secondary grid whenever there is a reversal of current flow through the protector. The network protector also operates automatically to reconnect its transformer to the secondary grid when conditions are such that the transformer will perform its normal function of delivering energy to the secondary system.

Automatic Operation

Introduction of the low-voltage network system was the start of full automatic operation of alternating current distribution systems. It also focused attention on the advantages of small transformer units with a large number of such units on each supply circuit and without the economic restriction of high voltage switching ahead of each small transformer.

Radial Feeders

The common type of distribution system in residential areas 25 years ago consisted essentially of large distribution substations, each supplied by a group of subtransmission circuits, and each supplying a large number of radial distribution feeders which were usually operated at 2,400 or 4,160 v. There was wide variation in the length and loading of the distribution feeders but in general both were kept as great as possible in order to keep the number of substations at a minimum. The number of substations, each with a full staff of operating personnel, was a major factor in determining the cost of distribution. The greatest disadvantage of this type of distribution was economic but it also created a serious congestion of circuits in the vicinity of the station and the size and loading of the distribu-

Prepared by T. J. BROSNAN, *Distribution Engineer, Buffalo Niagara Electric Corp*
with collaboration of Harold Cole, The Detroit Edison Co; D. K. Blake, General Electric Co; J. S. Parsons, Westinghouse Electric Corp

tion feeders made it difficult to maintain a suitable quality of service.

Automatic Reclosure

The basic pattern of general distribution has changed during the past 25 years and the cornerstone for that change was the introduction of automatic reclosing equipment for distribution feeders which made possible fully automatic substations without need for continuous attendance. This eliminated the major objection to smaller substations and permitted the design of distribution systems having the best economic balance between subtransmission and distribution circuits. It become practical to place the small automatic substations as close together as is economically desirable within a load area.

Following the practice initiated in the low-voltage network, the system design has been worked out so that several units in different substations are supplied from a single subtransmission circuit; automatic high-voltage switching is omitted from the substation units so as to minimize the differential in cost between a large number of small units as compared to a smaller number of large units on one subtransmission circuit. By establishing a reasonable uniformity of load and distance for the feeders supplied by a substation, it has been possible to use bus regulation and further simplify the general distribution system design.

Multi-unit Substations

These new developments in economic distribution system design have been worked out in two different forms. One is the small multi-unit substation with radial feeders. Each feeder is operated independently but provision is made for emergency tie connections between the feeders supplying adjacent feeder load areas. This type of system is shown schematically in Fig 2. The other type of system employing the same basic principles has been called the primary network system. It is usually made up of single transformer substations with the distribution feeders so arranged that they tie together adjacent substations in all directions. This type of system is shown schematically in Fig 3.

The modern radial system has certain advantages and disadvantages when compared with the modern primary network system. The selection of the type best suited for the supply of a specific load area should be made only after a careful study of that area.

Modern distribution systems of both types have proven to be very economical and extremely flexible in urban load areas. The size of each distribution circuit is kept relatively small so that the area interrupted in case of major trouble on a distribution circuit is correspondingly small. The voltage drop is relatively low and the general level of voltage is rather uniform throughout the load area.

Rural Systems

In the rural areas the same basic ideas have governed the development of the modern distribution system. However, the best economic balance between sub-

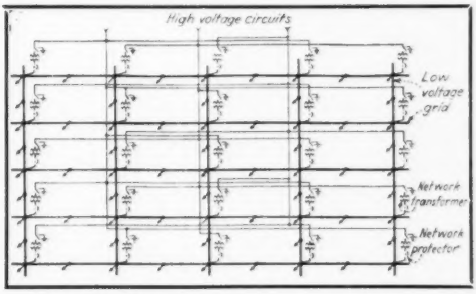


FIG 1—ESSENTIAL ELEMENTS of a low-voltage network type of distribution system

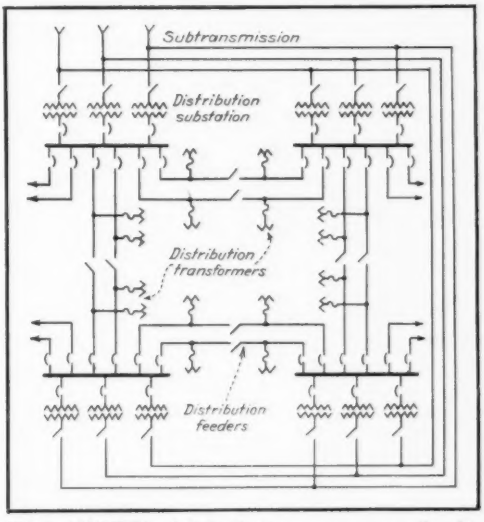


FIG 2—MODERN radial distribution system using small multi-unit substations

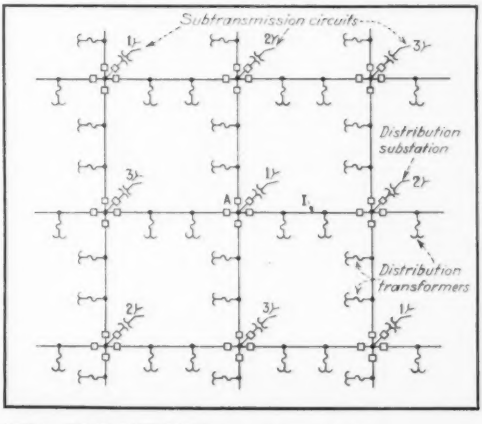


FIG 3—CONVENTIONAL primary network system

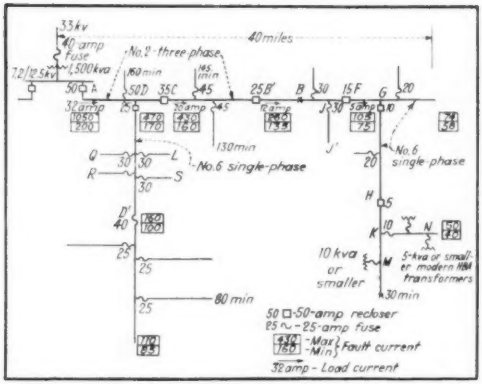


FIG 4—COORDINATED SYSTEM of protection for rural distribution feeder makes use of several instantaneous time delay reclosers for persistent and non-persistent faults

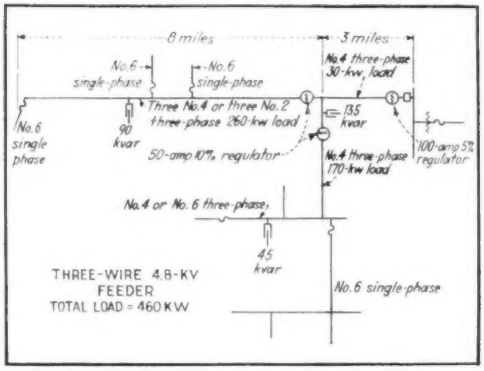


FIG 5—USE OF CAPACITORS and voltage regulators to maintain suitable service voltage

transmission and distribution circuits still results in long distribution feeders because of the low load densities that prevail in most rural areas. There have been some interesting developments during the past 25 years in coordinated systems of protection for such rural feeders. As a result it is possible today with the use of comparatively inexpensive equipment, to provide for the isolation of a relatively small part of a circuit when trouble occurs in that portion. Shown in Fig 4 is a typical example of a circuit so protected.

Capacitor Correction

The past 25 years have witnessed the development of the small shunt capacitor for use on distribution systems. The practice of supplying the reactive requirements of the distribution system and of the load through shunt capacitors has been growing rapidly particularly during the war and post war periods when the system capacity thus released has had such immediate value. The shunt capacitors are also being used in conjunction with induction or step-type voltage regulators to maintain proper service voltages on distribution feeders. A typical example is shown in Fig 5.

Capability of Secondary

This story about distribution system developments during the past 25 years would be incomplete without at least a brief reference to the work that has been done on the general distribution secondary systems. The 3-wire, 1-phase, 120-240-v system has become well established for general secondary distribution in residential areas. Studies seem to indicate that this system can accommodate economically load expansion far beyond present levels without the need of introducing either three-phase secondaries or higher secondary voltages for general distribution. Much study has been given to the economical arrangement of distribution transformers and secondaries.

A very common practice in urban areas today is to use a single size of secondary conductor, as for example No. 2, and to follow an established economic guide for the placing or the rearrangement of distribution transformers and for the subdivision of secondary mains for the accommodation of load growth. There has been a slow increase in the practice of banking distribution secondaries in order to minimize the voltage flicker caused by motorized equipment in the homes. Quite recently some equipment has been introduced for the coordinated protection of such banked secondaries.

Prospect of Improvement

Turning now to the future, it appears that the major consideration for many years will be the rearrangement of existing distribution systems in order to incorporate into them the economic advantages of modern design. The fundamental elements of economic distribution design are now well known. However, there are many variables that control the satisfactory application of those basic principles to the development of a distribution system for a specific load area. For example, the conditions prevailing in certain areas are today influencing the use of higher distribution voltages such as 12 kv and 13.2 kv while in other areas it is found more advantageous to expand the subtransmission system and to install small automatic substations for the supply of the usual distribution voltages. It seems that the period ahead will find the greatest effort exerted on the selection of the most satisfactory and most economic type of distribution system.

There is also much to be done, in the years just ahead, in the detailed design of our distribution systems in order to obtain safer construction, improved appearance and also construction less vulnerable to storm damage. Present efforts along those lines are undoubtedly only the start of a gradual program of improvement. The work that has already been done on aerial cable and lower cost underground construction represents a good start.

The economic factor above all others seems destined to exert a continuing major influence on distribution system design and operation. It is now well recognized that investment charges and operating charges for the distribution system are extremely important factors in the overall economic performance of every company.

Distribution Transformer

Successive development applied to tanks, bushings, windings, cores and cooling mediums. Gains achieved on standardization and lightning protection. Advent of the network, rural and dry types

TWENTY-FIVE YEARS AGO the distribution transformer had already reached a fairly high state of development as an efficient and reliable piece of equipment. The changes which have been introduced since that time have been of two general types. There have been numerous improvements made in the direction of lower cost, improved operation and greater reliability as new materials have been produced and more knowledge of the characteristics of load and of service conditions have been acquired. There have also been several outstanding developments occasioned by specific needs of the industry, created by new uses brought about by changes in the loads to be served.

IMPROVEMENT IN COMPONENT PARTS

Tanks

Tanks and their covers were formerly made of cast iron. About 25 years ago the change to welded sheet steel for these parts was begun and that material is universally used today. The chief advantage from this change was a considerable reduction in the total weight of the transformers, amounting to some 30%. This effected economies in handling, shipping, and mounting. Other advantages from the steel construction were easier adaptation to improved designs of tanks, covers, bushing pockets, etc; easier attachment of radiators, cooling fins, and other accessories; reduction in leaks and greater ease of repair (by welding). The protective finish of the steel tank against corrosion has been given a good deal of attention resulting in the use of improved methods of underfinish preparation and long-life finish coats.

A marked improvement in recent years has been the "sealed tank" design. This has accompanied the improvement in bushings and windings which will be mentioned later. By use of better clamping devices and better gaskets of synthetic rubber materials, the tanks have been made oil tight and practically air tight, thus preventing spilling of oil in shipping and handling.

Bushings

Bushings were formerly made of dry process porcelain with the insulated leads from the windings carried through them for exterior connection. In spite of anti-siphoning joints in the leads and compounding of the leads in the bushings, considerable trouble was encountered in the field due to oil siphoning and to entrance of moisture. The bushings were relatively weak in impulse strength and little was known of coordinated insulation. The modern bushing is made of wet-process porcelain of high mechanical strength, designed and mounted for coordination in impulse strength with the windings. Studs solidly fixed in the bushings prevent oil siphoning or leaking. They are connected to the winding leads inside the tank and are provided with mechanical connectors on the exterior ends whereby the line leads may be readily connected or disconnected. The bushings thus are part of the "sealed tank" design.

Windings

In the older distribution transformers, the windings were commonly impregnated with a solid gum of high dielectric strength. Insulation was designed largely on a 60-cycle basis, since knowledge of the nature of lightning surges and of the impulse strength of materials was meagre. The development of various surge recorders, of the cathode ray oscillograph, and of the surge generator led to a much better understanding of the nature of the voltages which a transformer must withstand. This allowed transformer winding insulation to be designed with high and consistent impulse strength, using materials better suited and more effectively arranged.

The gum impregnants, which tended to leave air particles contributing to low impulse strength, and which also tended to soften under heat and contaminate the oil, were abandoned in favor of varnish dips or shellac pre-treatment of insulation. At the same time, the sealed tank design allowed the shipment of

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OLD CAST IRON TANK TRANSFORMERS (top) compared with modern designs. (Courtesy General Electric Co and Westinghouse Electric Corp)

the transformer filled with oil, eliminating the nuisance and cost of separate oil handling. Oil filling under vacuum at the factory insured the maximum elimination of air and moisture before shipment. All this has made for greater reliability, that is, fewer failures in service and less customer interruption. This improvement has been accompanied and supplemented by improvements in lightning arresters and their use, which will be mentioned later.

Core

Twenty-five years ago transformer cores were made of hot-rolled silicon steel plates. The non-aging quality of this material was a considerable improvement over that of steel used in the earlier days of the industry. Further improvements, reflected in weight reductions, were made in the quality and use of this steel up to the late 1930's. At that time a much better material was introduced—a cold-rolled high silicon steel of greatly improved qualities. This steel could carry one-third more flux than the steel in current use at the time. As might be expected the adoption of this new core material has led to appreciable reduction in the size and weight of distribution transformers, amounting to an average reduction in diameter of about 8% and an average reduction in weight of about 25%. Resulting economy in cost of manufacture, shipping, handling, and mounting is obvious.

A major design problem which had to be met in using this new steel was due to the fact that it was of the oriented grain type, that is, the flux must pass through it in the direction in which it was rolled in order to gain the advantage in magnetic qualities. It was therefore necessary to revise the construction of the cores accordingly. The form originally adopted was that of a spirally wrapped "doughnut" but there have since been several variations in the shape and method of assembly.

Askarel

Although mineral oil is still used as a cooling medium in most distribution transformers, the past 17 years has seen the introduction of askarel, a non-inflammable synthetic cooling and insulating liquid. This material has been used in network transformers and has found quite wide acceptance in transformers for industrial, railway, and mining applications where fires and explosions are likely to be particularly hazardous and special prevention means are warranted.

Standardization

A very considerable factor in reduction in the cost of present day distribution transformers has been the standardization effected by the Joint Committee of the Edison Electric Institute and the National Electrical Manufacturers Association on Standards for Distribution Transformers. The formation of this Committee in 1938 was instigated by the numerous variations in designs which the manufacturers were being asked to produce. In one case, for example, a manufacturer was making 26 different designs in one voltage and size. It was believed that appreciable economies were possible in quantity production, if general agreement could be reached in the industry on the essential features of a basic standard transformer, with additional equipment available as accessories when required. This has proved to be the case.

In order to focus attention on the principal items affecting transformer design economies and to crystallize industry opinion, the Joint Committee established close liaison with electric power utilities and other users of transformers by means of a list of 100 "advisors" who, upon request, have furnished data and comments as the work progressed. This has been supplemented by presentation of exhibits and by discussions at various meetings of the sponsoring groups. The Committee's first report was issued in 1940 and has been followed by three other reports, perfecting and extending the first.

Standardization Benefits

The Committee is still continuing its work. Standardization has covered kva ratings, voltage ratings and taps, accessory equipment, arrangement and location of accessories and bushings, and terminal connectors. A noteworthy feature was the provision of jump-proof, direct pole mounting. Interchangeability of mounting and connections for all makes has been established. Standardized hangers for crossarm mounting have also been provided. Both single phase and three-phase transformers have been included.

These standards have been put into production by the manufacturers and are quite generally adopted by the users of transformers. It is impossible to evaluate

the savings which have been accomplished by this work in simplifying the manufacture and erection of transformers. The benefit is known to be considerable, however, and will continue to increase as the possibilities of the simplified features of direct pole mounting and the omission of taps become more widely recognized and accepted.

Lightning Protection

The largest single cause of transformer failures has been lightning. Not only have the transformers themselves been improved greatly in their ability to withstand lightning surges but also the lightning arresters and the methods of their application have been made much more effective. The better understanding of the nature of lightning surges, which was gained by the development of instruments for measuring natural surges in the field, has led to several marked advances in lightning protection.

1. The recognition of the need for lightning protective devices in immediate proximity to the transformer terminals.

2. The recognition of the need for low resistance grounds for the protective device for best protection.

3. The introduction and marked improvement of the valve type of lightning arrester and later of the expulsion type of arrester; also a better understanding of the protective characteristics of these types, their best field of application and their limitations.

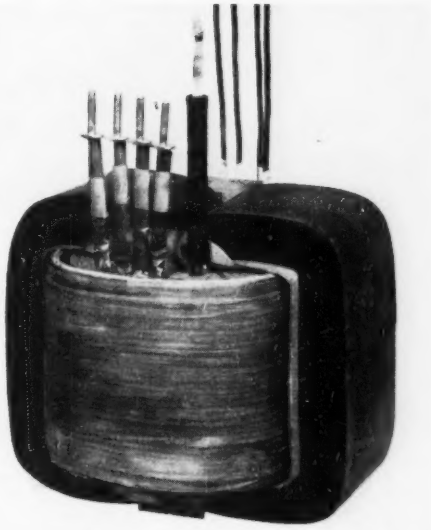
4. The introduction of the practice of interconnecting the lightning arrester ground connection with the secondary neutral at a distribution transformer, thereby reducing the voltage stress between the primary and scondary windings at time of surge discharge. Reductions of as much as 50% in transformer failures and of 75% in blowing of primary fuses by the adoption of this practice have not been uncommon.

Although this development of external lightning protection is not directly a part of the development of the transformer, it has been closely associated with it and has added greatly to the reliability of the service rendered to the customer by the transformer. Furthermore, the arrester protection has been incorporated into the assembly of the "self-protected" transformer which will be mentioned later.

NEW TYPES OF TRANSFORMERS

Rural Transformers

About 20 years ago the country-wide program of extending electric service to the farms got under way. The scattered nature of this load required that the distribution lines be designed and built as economically as possible, in order to make the service feasible at reasonable rates. The long-span farm line was the result. It was desirable, of course, that the cost of distribution transformers for this service be reduced to a minimum. This necessity led to the production of the so-called rural type transformer for use on circuits with grounded primary neutral. These transformers had a single primary bushing mounted in the cover, with the other primary lead tied inside to the case for connection with the grounded neutral. They were built for direct pole mounting, and other features were simplified. In some cases a lightning arrester mounted on the tank was provided. Others had an open spill gap only, and a fusible link in the primary lead, being intended for use without other lightning arresters or conventional fuses but protected in groups by a line recloser. The ratings originally covered were those most used on rural lines, namely, 1 and 3 kva; later, 1½, 3, 5 kva and up to 25 kva.



MODERN TYPE wound core (Courtesy General Electric Co)

No definite figures on the saving in cost effected by these transformers are available but statements made at the time claimed costs some 15% below that of the previous conventional type. The experience gained with this rural type of transformer had considerable influence on the features of the EEI-NEMA standards later adopted for distribution transformers in general.

Self-Protected Transformer

A significant development in the early 1930's was that of a distribution transformer with the protective elements all assembled integral with the unit. For lightning protection, arresters of the expulsion type are mounted inside or on the outside of the tank. The transformer insulation strength is coordinated with the breakdown and discharge characteristics of these arresters so that they will provide adequate protection. The arresters are connected on the discharge side to the tank, thereby limiting the voltage stress between the high voltage winding and tank. The voltage between low voltage winding and tank is also limited by coordinated bushings. The discharge path is completed by grounding the tank either directly or through a discharge gap. The secondary neutral

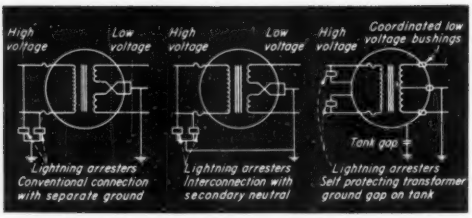
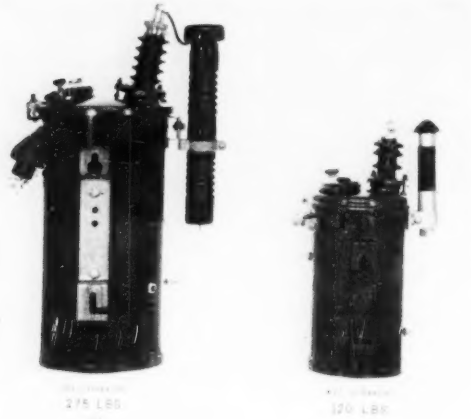


DIAGRAM of lightning arrester connections



RURAL TYPE transformer (Courtesy General Electric Co)

is connected to the same ground. This protective arrangement is similar in principle to that described as "interconnection of grounds" under lightning arresters.

Protection to the line against short circuits in the transformer winding is provided by a fusible link in the primary leads inside the transformer which disconnects the transformer from the line in case of an internal fault.

Secondary Breaker

On the low voltage side, overload protection is afforded by a small circuit breaker inside the tank. This breaker is actuated by a bi-metallic element submerged in the same oil with the transformer windings and carrying the same current. The combination of the oil temperature and the actual current produces a temperature in this element similar to that of the windings and the circuit breaker operation is therefore controlled by this simulated winding temperature rather than by the magnitude of the current. Thus the transformer is allowed to carry loads well up to the point of thermal damage, regardless of variations in actual load, time of loading, or ambient temperature—the most economical method of loading. On most of the ratings warning lights are provided, also actuated by the bi-metallic element, which indicate when the maximum safe operating temperature has been reached as well as when the breaker has tripped.

This transformer, therefore, offers a self-contained unit which comprises effective lightning protection, protection against internal short circuits, and means of loading by copper temperature to the maximum allowable amount. It has had good acceptance by the utilities.

In a more recent modification of this type of transformer, an alternate design using an additional low voltage circuit breaker is provided whereby the transformer is adapted to operation in secondary banks, which are discussed later in this article.

Network Transformers

One of the outstanding developments in electrical distribution systems in the past 25 years has been the multiple feed a-c low-voltage network for high-density metropolitan load areas. Transformers for vault installation in 300-kva to 1,000-kva ratings have been developed for this particular service. These are adapted to assembly in a complete network unit, each unit having a high-voltage disconnecting and ground switch on one end and a low voltage network protector on the other end. Askarel-filled transformers of this type are available as well as those with conventional oil. This low-voltage network type of distribution has become standard for "down town" city areas throughout the country.

A supplementary development in this connection has been the overhead type of network transformer in sizes from 75 to 150 kva for mounting on poles or platforms in lighter density network areas where complete underground distribution is not required.

Load Center Assemblies

The load center unit for industrial and mining use consists of an askarel-filled or dry-type transformer with metal-clad switchgear. By use of these units, circuits at primary voltage may be extended to these load centers throughout a large plant, with resulting flexibility and economy.

Dry-Type Transformers

As previously mentioned under the heading "Askarel" the elimination of mineral oil from transformers is desirable, particularly for network use or for industrial locations where the hazard from fire or explosion is greater than on pole top installations. In recent years there have been some outstanding developments in the field of high-temperature insulating materials, one of them being the silicones. A line of dry-type distribution transformers for indoor use has been produced and found considerable favor on industrial distribution systems. Very lately, enclosed units for outdoor or underground installation as network transformers or in load unit assemblies have become available. Their lighter weight and the elimination of oil are attractive features for this purpose, if experience proves them to be otherwise satisfactory and economical.

Secondary Banking

For many years secondary banking, or the connection in parallel of several transformers at different

locations along a continuous secondary, has been practiced on some power systems—one at least has done this for over 40 years. There has been much greater interest in and more widespread use of banking in recent years, stimulated by realization of the economy possible and by the general use of small, frequently started motors on refrigerators and heating plants in residences. The voltage dips due to the starting of these motors have become a controlling factor in distribution design. By banking transformers on the secondary, the starting current at any point is divided between two or more transformers and hence the voltage dip reduced. In addition, banking affords greater reliability of service and economy in better average loading of transformers.

Temperature Loading

It was recognized many years ago that transformers could safely be loaded intermittently far beyond the name plate rating for continuous load. Since the characteristic load on distribution transformers is usually of a relatively high peak for a relatively short time, economy is effected by allowing that peak to go to as much as 150% or more of the name plate rating, the safe amount varying, of course, with the characteristics of the transformer, the ambient temperature, and the shape of the load curve. It is quite common practice now to take advantage of this economy from loading by copper temperature rather than by kva. The provision for controlling this load in the self-protected transformer has been mentioned. Where the conventional type of transformer is used, similar results can be approximated by careful study of load characteristics and periodic measurement of transformer loading.

Future Possibilities

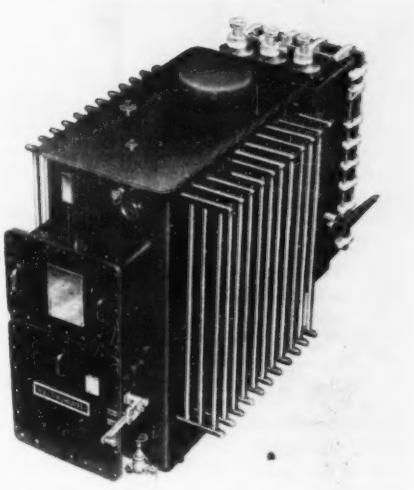
It is believed that the brief review which has been given of each of a number of the outstanding developments in distribution transformers during the past 25 years will indicate that the industry has been active and alive to the possibilities of making improvements and lowering costs. It is to be expected that such activity will continue in the future. Much of it can probably not be foreseen at this time. There are a few items, however, which might be mentioned as being either distinct possibilities or highly desirable.

There is considerable promise of the production of a dry-type distribution transformer for pole top installation. The advantage will be less weight and lower maintenance. It seems possible that on such a transformer the case might be reduced to a minimum or perhaps be eliminated entirely.

Standardization should be extended to cover all types of distribution transformers as far as possible—work is now proceeding to that end. It would be desirable if the electrical characteristics, impedance and losses, could be similarly covered, at least to the extent of establishing similar values for different makes. In this connection some review should, no doubt, be made of the most economical ratio between core and copper losses in view of modern load characteristics and loading practices. Low impedance is desirable from the standpoint of reducing voltage drop and voltage dips. Considerable attention was given this problem about ten years ago. A renewed study of the most advantageous practical relationship might result in constructive betterment in design.

There are possible improvements in the material or finish of transformer tanks in the interest of longer life and less maintenance.

If one might indulge in a little speculation, it could be imagined that load densities in residential areas could increase to a point where there would be a demand for an economical installation of an individual transformer at each pole from which service is taken. This might also lead to need for buried or semi-buried types—one at each service perhaps.



NETWORK UNIT (Courtesy Westinghouse Electric Corp)

LOAD CENTER UNIT with dry type transformer (Courtesy Westinghouse Electric Corp)

Distribution Reliability

Continuity of service has benefitted from better construction practices, faster fault clearing, improved connections, more reliable transformers, reclosure and sectionalization, sounder anchoring, adoption of underground and aerial cable, networks, banking and multiple lighting

TWENTY-FIVE YEARS AGO electric service interruptions in residential areas went almost unnoticed unless they occurred during the evening lighting period or on wash day or ironing day. Today households are so completely dependent upon electric service at all times, that they are inconvenienced by an interruption even at the wee hours of the night when electric blankets grow cold, heating and refrigeration systems stop functioning and electric clocks lose time.

Some of the methods and devices which have been developed for improving reliability have been inexpensive, or even cheaper than previously used methods. Other schemes are quite expensive and require good judgment on the part of the engineers and management in estimating the desires of consumers in regard to the quality of service versus its price.

Network and Radial

The most reliable alternating current service known to the distribution engineer today is being rendered by the underground secondary network (Fig 1). This system has been developed during the last 28 years and is being used in the business districts of approximately 192 cities. The cost of the underground secondary network prohibits its use in areas with low load density except where the utmost in reliability is necessary.

The simple radial circuit stands today as the most commonly used form of electric distribution in both urban and rural areas (Fig 2). Intermediate orders of reliability are rendered by spot networks, overhead secondary networks, overhead primary networks, loop circuits and various forms of dual feed. Many things have been done to improve the service reliability of all these forms of electric distribution and some of these will be discussed.

Reliability of Conductors

Distribution engineers have learned many ways of minimizing conductor failures during the last quarter century. Faster deenergization of circuits has helped reduce the number of conductor burndowns. Wider spacing of both primary and secondary conductors has helped reduce the number of flashovers and the self-clearing of power arcs when once struck. Development and use of both initial and final sag curves has contributed to more accurate sagging of distribution conductors. Some companies pre-stress conductors at time of installation as an alternative method of obtaining correct final sag.

Twenty-five years ago soft drawn weatherproof conductors were used almost exclusively for both primary and secondary construction. Hard drawn and medium hard drawn conductors have since been used to greater extent. Bare conductors have also been used more extensively where tree and space limitations permit with resultant improvement in economy and reliability. Bare conductors are inherently stronger because of less weight, less resistance to wind and less glaze accumulation. They also have much better burndown characteristics principally because arcs do not remain in one spot.

Synthetic Coverings

Where covering is desirable because of tree conditions, space limitations or legal requirements, neoprene, polyethylene and superior types of paper and braid coverings are now available. Tree wire is also now available which has greater surface resistance and reduces the number of burndowns caused by electrical discharge.

Breakage of tie wires has been reduced by the use of the double tie instead of the single tie at points of support. Reinforcing ribbon or rods help to reduce conductor failures on long span type construction. Reinforcing rods may be of the straight type held in place by clamps or of the preformed type which require no clamps. Improved types of strain insulators and clamps have been developed for the attachment of distribution conductors to terminal and junction structures.

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Several Conductor Materials

Twenty-five years ago there were four principal choices of conductor materials: copper, copper clad steel, and aluminum with or without steel reinforcing. Since that time and especially during the last decade many new types of conductors have been made available to the distribution engineer. These include composite cables of copper and copperweld steel stranded together, composite cables of copper and galvanized steel stranded together, composite cables of copper and bronze, and galvanized steel with improved strength and electrical resistance characteristics.

There has been considerable activity in the development of factory assembled and field assembled types of aerial cables in recent years. Neoprene is commonly used for the outer covering because of its ability to withstand the elements, and either rubber or varnished cambric is commonly used for insulation. Aerial cables usually cost more than open wire type construction and application is ordinarily restricted to places where tree conditions or space requirements are severe; for hazardous locations near buildings, windows and fire escapes, and where appearance justifies the additional expenditure.

Reliability of Poles and Fixtures

During the last two decades the pole class system of grading poles according to strength has been developed and now makes it much easier for the distribution engineer to design economical lines meeting strength requirements.

Modern full length pressure treatment of poles has materially lengthened the average life as compared with pole treatment methods used a couple of decades ago. Similarly the treatment of crossarms results in longer life. On single phase multiground type circuits, it is now common practice to eliminate crossarms entirely by the use of pole-top pin-type construction (Fig 3). Where this can be done, the structure is stronger and less likely to fail during storms.

Reliability of Transformers

Modern distribution transformers are more reliable today than a quarter century ago by virtue of improvements in design, manufacturing methods and in the way they are connected to distribution systems. Improvements in design include larger bushings, higher impulse strength of windings, sealed construction and other improved methods of excluding moisture, better lightning arresters, fuse cutouts and fuse links. Some manufacturers supply distribution transformers with inbuilt lightning arresters and inbuilt circuit breakers for radial or banked usage.

Operating companies have improved transformer reliability by fusing for short circuit protection rather than protection against overload; by connecting lightning arresters on the source side of fuse cutouts, by interconnecting lightning arrester with secondary grounds and by converting from delta to wye distribution circuits having a common neutral system of low resistance to ground. Improved methods have been developed for measuring this resistance.

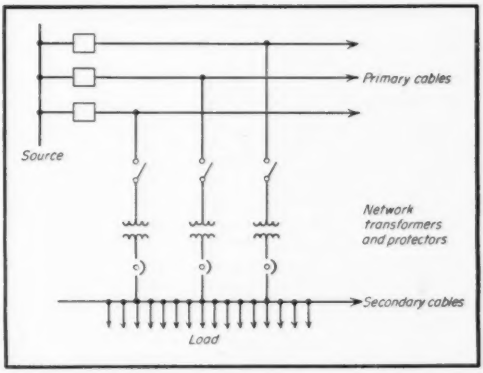


FIG 1—SECONDARY NETWORK. In case of fault on a primary cable the network protectors isolate the faulted cable and the remaining circuits carry all the load. In case of fault on the secondary system the secondary cable burns off or limiters deenergize the faulted section

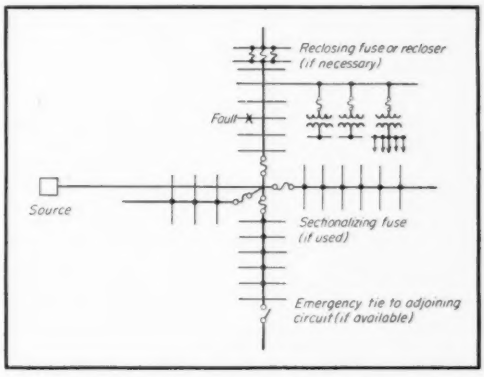


FIG 2—RADIAL CIRCUIT. Persistent fault causes service interruption (1) to all customers if sectionalizing fuses are not used, or (2) to only part of the customers if sectionalizing fuses are used. Coordination of fuses with instantaneous and time-delay relays prevents non-persistent faults from blowing the sectionalizing fuses

Transformer Loading

The statistical method of loading distribution transformers has been developed in recent years and compares favorably with other methods in both accuracy and cost. Many companies now rely on this method exclusively in residential areas where a definite relationship between annual consumption per customer, number of customers, and transformer load can be established. The prevention of transformer burnouts is in the direction of both economy and service reliability. New and improved instruments are now available for ascertaining the maximum load on transformers and conductors in the field.

The "package unit" substation, where transformers, metal clad switchgear and associated equipment are manufactured on a repetitive basis for network, radial

and other operating schemes, has been developed during the last quarter century and offers a high degree of reliability, compactness and acceptable appearance.

Fuse and Recloser Reliability

Modern fuse cutouts, with horn fiber lined tubes for arc-extinction; with indicating, drop-out, or repeating features; with modern fuse links of accurately known time-current characteristics are a great improvement over the old plug type cutouts and string type fuses. There are now special cutouts and fuses for extra heavy interrupting duty, dual element fuse links which combine the desirable effect of reduced lightning blowing and improved short circuit protection; improved limiters for both underground and overhead secondary network systems; and fuse links with special time-current characteristics to provide coordination with other fuses, relays and reclosers.

Perhaps no single thing has contributed more to service continuity on urban distribution and rural lines than the development and careful coordination of fuses, relays and reclosers to: First, test whether faults are persistent or transient, and then to automatically isolate the persistent faults.

Coordination and Sectionalization

Some companies now use sectionalizing fuses on 100% of the load on urban distribution circuits under the premise that the sectionalizing fuses are never to blow except where there are persistent faults. This means that the relays and circuit breakers must be able to handle an unlimited series of quickly recurring transient faults such as occur during lightning and wind storms. Successful operation depends on knowledge of fault current at various points on the circuit and accurate coordination of fuses with instantaneous and time-delay relays. A number of electrical apparatus manufacturers have done a good job of supplying reclosers which will perform these functions on rural lines. Reclosers of higher current carrying and interrupting ratings are now being manufactured for rural and urban usage.

Other developments include line shorting devices to extinguish arcs and reduce conductor burndowns; reclosers which will lock either open or closed on the final operation; and motor operated air break switches which will automatically sectionalize distribution lines.

Splice and Connector Reliability

A quarter century ago the standard method of splicing and tapping copper distribution conductors was to "serve and solder". Workmen often spent an hour or two making a single splice or tap. The skill of the workman had a great deal to do with the effectiveness of the splice or tap. Today the distribution engineer has a wide choice of mechanical devices which require less time and less skill and can be applied to hard drawn conductors because they do not require solder. For making taps and connections at junctions and terminals he has the choice of split bolt type connectors, various other bolted type connectors, compression type connectors, brazed connections and hot line clamps. For making splices he has a choice of twist sleeves, compression sleeves—either hydraulic or mechanical—and the automatic wedge type splices. Connectors may be plated with tin, cadmium or zinc to reduce oxidation and to facilitate connecting conductors made of different metals. Compounds are also available which reduce the rate of oxidation at connection points.

Some fine studies have been made in recent years of the various methods of connecting and splicing electric wires and cables; of the importance of properly cleaning surfaces; of the nature of oxide formations; and of ways to minimize oxidation. The dissemination and utilization of this information by electric operating companies will undoubtedly result in continued improvement in service reliability.

Reliability of Anchors

Distribution engineers use the "chain is no stronger than its weakest link" philosophy in much distribution design work, but one outstanding exception is anchorage. Experience has taught that when the weather imposes glaze or wind loading to the point of destruction lines can be rebuilt and service reestablished much more quickly if terminal and corner structures are found intact.

During the last two or three decades the trends in distribution system anchorage have been toward improved types of expanding and screw type anchors; away from shim plates and J-hooks and toward eye-bolt type pole attachments; away from mild steel strand and toward higher strength strand; away from insulators in guys and toward effectively grounded anchors and guys. In selection of guy strand the distribution engineer today has a choice of at least five grades of galvanized steel according to strength in addition to stainless steel and copper-weld steel.

The art of applying anchors most effectively has progressed during the years. This includes specifications such that the strength of various sizes of strands, bolts, rod and plates is properly matched in complete assemblies. The anchor assemblies of various strength are then specified according to the number, size and tension of loaded conductors and to the lead-to-height ratio of the guy strand.

Service Drop Reliability

Perhaps the one thing that has contributed the most to service drop reliability has been the almost universal trend from horizontal to vertical configuration of secondary conductors. This permits the maintenance of adequate clearance between service conductors all the way from pole to building. Other developments include concentric, parallel and triplex types of insulated service cable; improved devices and methods of attaching service cables and open wire drops to poles and buildings, and for keeping service drops away from trees. Developments include neoprene and polyethylene type coverings and the use of aluminum for service conductors.

Reliability of Underground Networks

Since the first a-c secondary networks were originated a little over 25 years ago, there have been numerous improvements in underground equipment and methods.

Transformers for underground network system usage have been furnished with non-inflammable cooling liquids and with network protectors mounted on the transformer. Submersible network transformers of the dry type are also available and are being installed on several systems.

Rigid schedules have been set up and followed on high voltage testing of cables, inspection of equipment, and load checking. Cable fault locating equipment has been improved to a high degree of effectiveness. Secondary cables on network systems have been either carefully sized to insure rapid burnoff, or protected by limiters. Companies located inland where water tables are low have provided drainage from vaults and manholes or have setup procedures to de-water them with a portable pump or with permanently installed and automatically controlled pumps. Companies located near the coast have tended toward hermetically sealed units and welded covers.

Cable runs subject to stray current or galvanic electrolysis have been protected by introducing corrective counter direct current supplied from rectifiers or buried anodes (cathodic protection). Protected sheath cable has been used extensively to minimize sheath corrosion. Various synthetic coverings have been used on lead sheathed cables. Bituminous coatings are commonly used for the protection of pipe type high voltage cables.

Street Lighting Reliability

One of the most baffling problems in distribution system engineering is to design a series street lighting system which will continue to operate during wind storms. The circuit is often several miles long, of minimum conductor size, continually turning corners and terminating in lighting fixtures which are susceptible to wind.

Trends which have helped improve the continuity of series street lighting service are; development and use of automatic sectionalizing devices; use of isolating transformers on minor portions of the circuit; use of smaller outdoor type constant current transformers near the load instead of larger indoor type constant current transformers at power plant or substation; better tree trimming and tree wiring; use of improved bracket-type instead of suspension-type lighting fixtures; and group replacement of lamps.

Multiple Lighting

Many companies are using multiple instead of series circuits for street lighting in new areas. These may be either direct or pilot wire control. In the latter case, the use of pilot wires which are energized in the daytime and deenergized at night is in the direction of greater continuity of street lighting service. At least one manufacturer offers a system of "wired radio" control of street lights.

Some companies are using overhead construction exclusively on new ornamental high intensity street lighting projects where underground construction would have been specified a few years ago. This has been facilitated by the trend toward 25 and 30-ft mounting heights of luminaires. In case of failure, service can be restored to the overhead circuits more quickly than where underground circuits are used. At least one company is using aerial cable extensively for serving multiple type ornamental street lights.

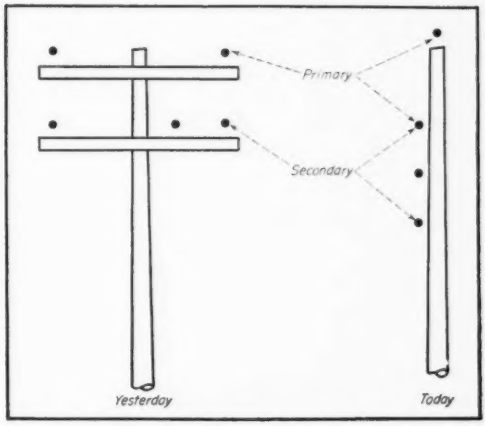


FIG 3—TWO CROSSARMS and one conductor are eliminated, on single-phase common-neutral multiground type construction

Operation and Maintenance

The development of operating procedures has had much to do with the gains that have been made in distribution system reliability. The selection, training, allocation and physical distribution of maintenance and operating personnel determine to a large extent the time required to restore service after an interruption. Such apparently non-related factors as road and communication facilities must be considered. Personnel must be trained to recognize and handle the special problems resulting from the simultaneous operation of many automatically controlled motors after prolonged service outage. Predetermined plans for handling emergencies, for transferring load from one circuit to another, for melting glaze off conductors—all pay dividends in improved reliability.

An adequate tree trimming program; the routine inspection of poles, services, and other components of the system; the continual moulding of the distribution system to conform with construction standards while it is being reinforced to carry additional load; the constant development of constructon standards, purchase specifications, and engineering guides; the systematic recording of cases of trouble to provide a guide for improvements by the manufacturers of the equipment and for improved engineering designs and operating procedures—these all pay dividends in service continuity as well as other benefits.

Future Trends

So much for the last quarter century. Let's have a look at the next one. Anyone who attempts to predict the future is "sticking his neck out", but the author has had the assistance and advice of some of the best distribution engineers in the nation, so here goes.

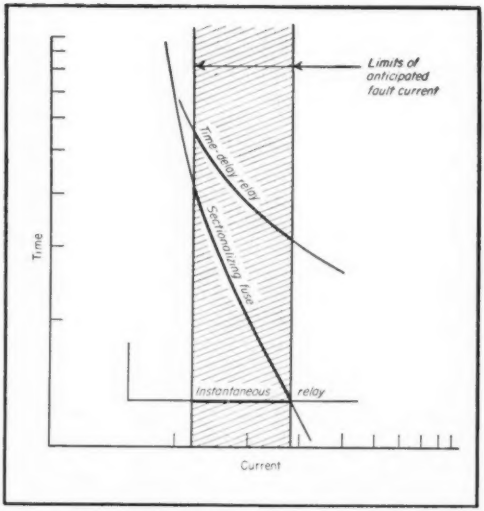


FIG 4—SECTIONALIZING FUSE operates slower than instantaneous relay in case of non-persistent fault and faster than time-delay relay in case of a persistent fault. (Compare with line diagram of Fig 2)

The use of bare conductors for primary distribution will increase in those localities where tree conditions, space limitations and legal requirements will permit. The superior burndown characteristics of bare conductors have been proved conclusively. Bare conductors are stronger by virtue of less weight, less resistance to wind and less accumulation of glaze. The money spent for weatherproof covering materials will be spent more wisely for additional clearance between conductors and from trees. Legal barriers to the use of bare wire will gradually be removed. The use of bare conductors for secondary mains in residential areas will increase for similar reasons.

If present price trends continue, aluminum with and without reinforcing will be used to greater extent for primary, secondary and service conductors.

The use of aerial cable for both primary and secondary construction will increase where appearance, clearance from trees or buildings, and service reliability warrant the additional cost. Aerial cable will be used as an economical alternative to underground construction where applicable. It is too early to predict the trend of preassembly versus spinning in the field. Cheaper insulating materials for aerial cables and underground cables would be a boon to these types of construction.

The industry has not yet attained the full benefits of secondary banking, especially in lightly loaded areas. There will be more in the future.

The use of the statistical method of supervising the load on distribution transformers in residential areas will increase. Someone may succeed in applying this method to transformers in commercial areas. The trend toward the intentional overloading of distribution transformers will continue in high load density areas but will diminish in low load density areas. There may be need for extra-low-impedance distribution transformers in the 5, 10 and 15-kva range to help control voltage flicker in lightly loaded areas.

Networks, Fault Isolators

Trend toward use of the 120-208-v secondary network to provide the utmost in reliable service is well established and will continue into the commercial areas of smaller and smaller cities—with overhead transformers and conductors where the cost of underground construction is not justified—with aerial cables for both primary and secondary circuits where open wires are considered objectionable.

The use of devices to automatically determine whether faults are transient or persistent and then to isolate the latter are being used extensively on rural type lines. Excellent reclosers and fuses with accurately known time-current characteristics are now available. This trend will continue in rural areas and the same principles will be applied more and more to urban areas. A few companies are now using sectionalizing fuses on 100% of the load with the fuses coordinated to blow only in case of persistent faults. This trend will continue.

The trend from delta to wye primary distribution circuits will continue, as will also the trend toward higher distribution voltages such as 12.5 kv. The economy and operating advantages of the common primary-secondary multiground neutral system in urban as well as rural areas is well established and its use will be extended into areas where there are now separate primary and secondary neutral conductors.

The economy of using capacitors on primary distribution systems is well established. If the price of secondary voltage capacitors can be brought anywhere near that of primary voltage capacitors, the trend can easily shift away from capacitors on the primary system and toward the use of capacitors on secondary systems where they will perform all of the functions they do today plus release of transformer capacity and further improvement of voltage.

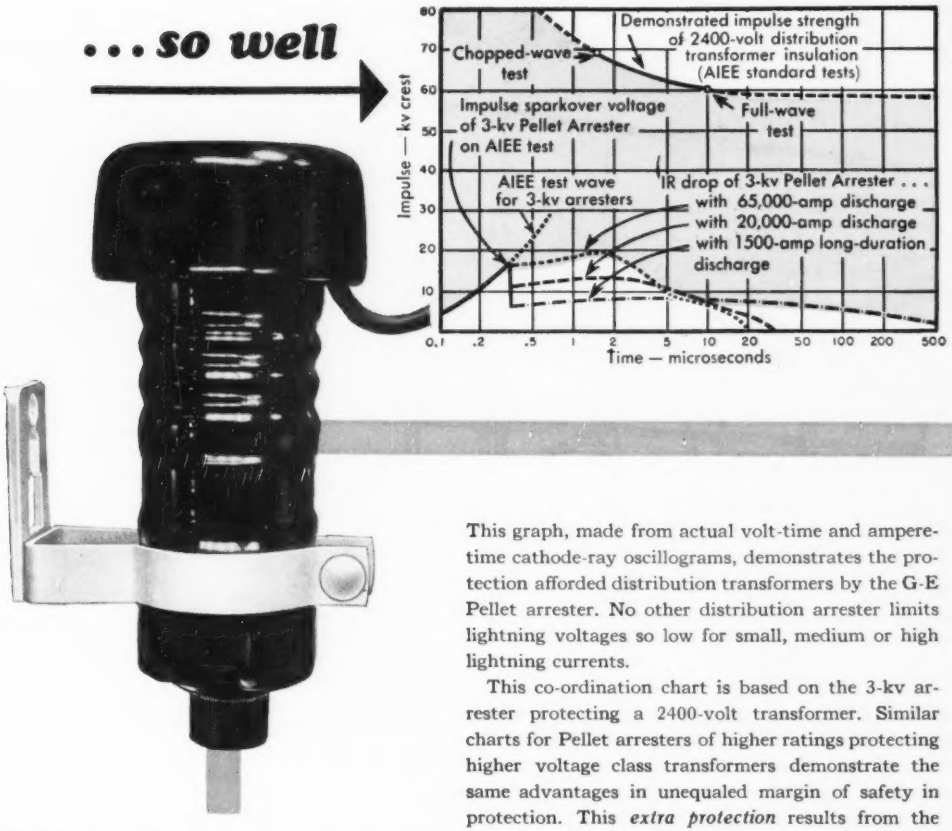
The trend toward 25 and 30 ft mounting heights for ornamental high intensity street lighting systems means that the same poles—steel or wood—which support the luminaires, can also support overhead conductors. Hence, the prediction is made that the trend will be away from underground street lighting systems. The overhead conductors may be aerial cable for appearance sake.

The trend toward multiple instead of series street lighting circuits will grow. In pilot wire control systems the trend will be toward pilot wires that are energized in the daytime and deenergized at night—for more reliable street lighting. The simplest and probably most reliable multiple street lighting system uses a photoelectric or equivalent controller to directly connect a small group of street lights to the established secondary system. The future of this system depends entirely on what mass production methods can do to lower the initial as well as the operating cost of controllers.

No other distribution arrester

Protects

. . . so well



The G-E Pellet arrester is also "tops" for endurance. It is the *only* distribution arrester with series gaps sealed in dry, inert nitrogen (N_2)—keeping gap electrodes bright as new during years of service operation. Pellets, themselves, are of lead peroxide—a distinctive valve element, self-protecting against service moisture—unaffected by condensation, or humidity. Pellet arresters have large discharge capacity—they withstand easily the AIEE and NEMA standard 65,000 ampere impulse test.

This graph, made from actual volt-time and ampere-time cathode-ray oscillograms, demonstrates the protection afforded distribution transformers by the G-E Pellet arrester. No other distribution arrester limits lightning voltages so low for small, medium or high lightning currents.

This co-ordination chart is based on the 3-kv arrester protecting a 2400-volt transformer. Similar charts for Pellet arresters of higher ratings protecting higher voltage class transformers demonstrate the same advantages in unequaled margin of safety in protection. This *extra protection* results from the combination of low sparkover voltage and exceptionally low IR drop, that together hold lightning voltages to lower levels than does any other distribution arrester.

You buy better protection when you buy Pellet arresters! The Quality-Standard of the industry for more than 25 years.

Apparatus Department, General Electric Company, Schenectady 5, New York.

GENERAL ELECTRIC

Which meets your system requirements?

coordinated substations?

For overhead subtransmission circuits

Westinghouse

PLANTS IN 25 CITIES . . . OFFICES EVERYWHERE

WESTINGHOUSE

MODERN EQUIPMENT FOR BETTER DISTRIBUTION SYSTEMS

. . . . unit substations?

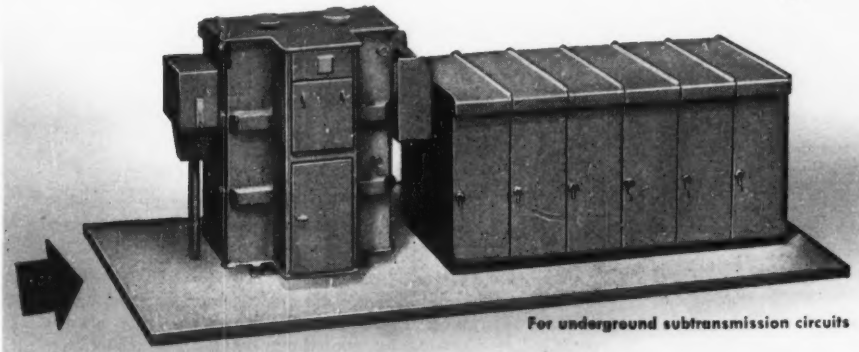
Today, *modern* substations for any system requirement may be purchased in two basic forms . . . as *Unit Substations* or *Coordinated Substations* . . . both supplied by Westinghouse.

Westinghouse helped introduce the *Unit Substation.* This type of substation is designed, built, tested and shipped complete . . . ready for connection to your system. Briefly, a *Unit Substation* consists of a transformer, and the necessary switchgear, combined to form an articulated unit to which the subtransmission and primary feeder circuits can be directly connected.

The *Coordinated Substation* consists of one or more *Unit Substations* with complete overhead terminating structure and any necessary terminating facilities. This equipment is shipped in easily-installed, factory-assembled and prefabricated sections.

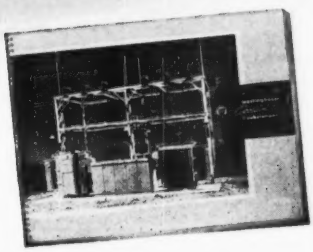
Westinghouse can supply a complete substation in *any* form . . . from incoming line to outgoing feeder . . . for *any* system. Whatever your power distribution requirements may be . . .

YOU CAN BE **SURE**
IF IT'S Westinghouse



For underground subtransmission circuits

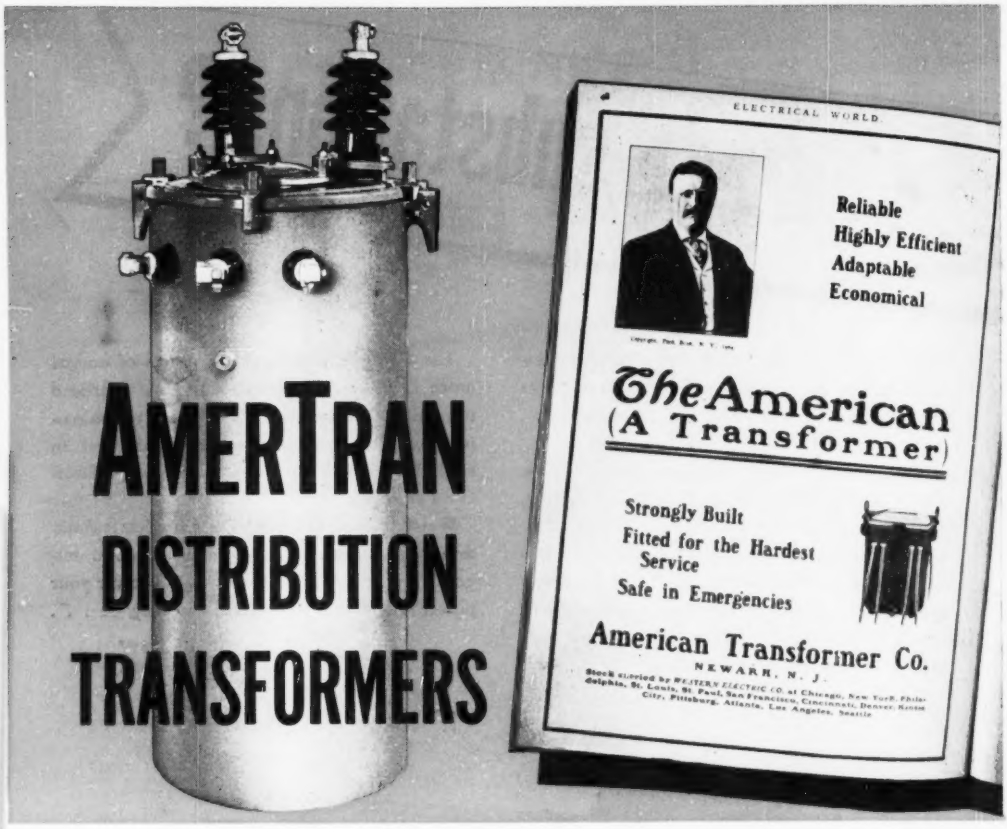
Here's the Complete Story **ON WESTINGHOUSE COORDINATED SUBSTATIONS!**



This 86-page book presents the standardized Westinghouse line of Coordinated Substations. Fact-filled pages of photographs and line diagrams give you complete information on all types . . . covering all basic requirements from the simplest to the more involved types of distribution substations.

To get your copy, call your nearest Westinghouse office. Ask for booklet B-4061 or write Westinghouse Electric Corp., P. O. Box 868, Pittsburgh 30, Pa.

J-97133



...a long line noted for long life

IT was about forty-five years ago that we ran the full page advertisement in Electrical World that appears in reduced size above. The gentleman with the mustache was, of course, Theodore Roosevelt, who was then finishing his first term as President.

That mysterious object in the lower right hand corner of the advertisement is an AmerTran Distribution Transformer. Its complicated cast iron construction is obsolete by today's standards, but it was the last word in transformer efficiency at the time.

By contrast, the newest AmerTran Distribution Transformer, also shown above, is a notable example of the modern trend toward simplicity in design and careful selection of materials, to insure uninterrupted service. A streamlined welded steel tank, improved materials in core and coil, ingenious design of low and high voltage bushings and other parts, make it difficult to understand how it would be possible to build a better transformer.

Yet, as time goes by, we know there will be improvements. For AmerTran engineering is never static. AmerTran engineers are always looking for something better. Yes, AmerTran will build distribution transformers as different from today's product as present models are different from the "gay nineties" design in our advertisement of almost a half century ago.

AMERTRAN

MANUFACTURING SINCE 1901 AT NEWARK, N. J.

AMERICAN TRANSFORMER COMPANY, 178 Emmet Street, Newark 5, N. J.

For More Than Sixty Years

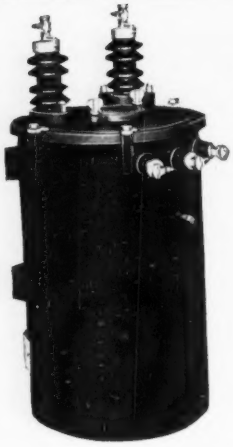
CRESCENT WIRES & CABLES

Have Played A Leading Role In The Growth Of The Electrical Industry

OVER 60 YEARS EXPERIENCE

CRESCENT INSULATED WIRE & CABLE CO.

TRENTON, NEW JERSEY



The inside story about

MOLONEY *HiperCore* DISTRIBUTION TRANSFORMERS

The inside story about Moloney HiperCore Transformers is centered around the material used in the cores. By using highly efficient oriented silicon steel it is possible to work the cores at higher flux densities than formerly. With the *total* flux requirements remaining practically unchanged, working the oriented steel at higher densities than practical with ordinary silicon steel, results in smaller cross-sectional areas of cores with a consequent reduction in weights.

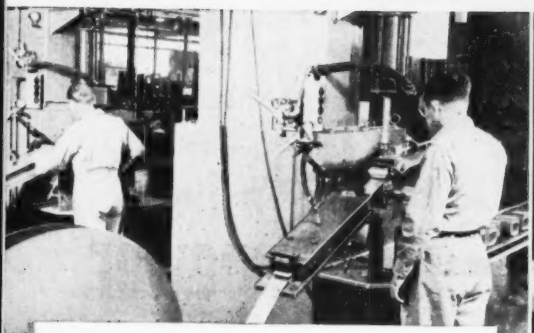
The smaller cores permit the use of smaller windings, smaller tanks and less oil. This results in lighter weight and smaller transformers which are easier to install and handle generally, and take up less space on the poles. Reductions in size and weight have been made without sacrifice in all-around performance. In fact, HiperCore Transformer operating characteristics are better . . . voltage regulation has been improved . . . greater short-time overloads can be carried.

Illustrated are a few of the operations involved in the manufacture of HiperCore Transformers indicating the careful attention given to every detail in order to assure unexcelled on-the-job performance.

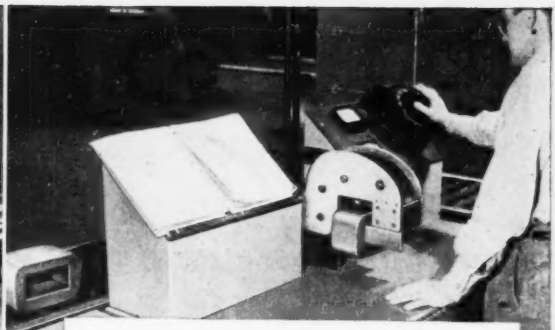
ME49-10

Testing voltage ratios at various tapchanger settings, to make certain that tap leads have been connected to proper studs, and that inter-coil connections are correct.

Placing core-and-coil assemblies in tanks after they have passed through oven which removes any moisture which may have been absorbed from the air, and also cures adhesive on core faces.



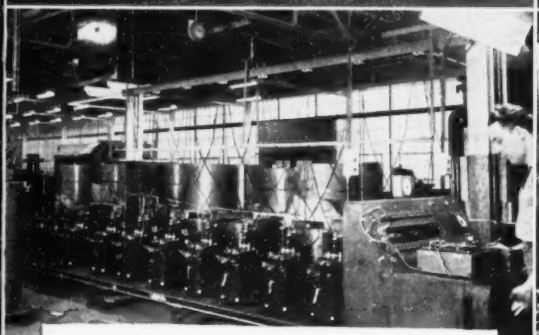
Cores are wound of oriented silicon steel. Winding machines are semi-automatic, stopping when proper thickness of winding is reached. End of core strip is spot welded.



Following winding of the cores, they are annealed in bell-type furnaces in a nitrogen atmosphere and are then given an initial test for losses as illustrated above.

Placing windings into position over U-shaped core pieces. Prior to this operation, cores have been impregnated, baked, cut, etched, and tested a second time.

Connecting tap leads from winding to tapchanger studs. On opposite side of assembly line, terminals are brazed to low voltage leads. Previous operations included applying adhesive to core faces, banding core pieces, and attaching frames.



After bushings have been installed, the tanks filled with oil, and the transformers vacuum treated to remove any entrapped air from the oil or windings, final electrical tests are made.

MOLONEY
ELECTRIC CO.
Sales offices in all principal cities
FACTORIES AT ST. LOUIS 20, MO.
AND TORONTO, ONTARIO, CANADA

LVD Flex-a-power

STOP, LOOK AND READ HOW EASILY

CUTS INSTALLATION COST

KEEPS MAINTENANCE LOW

GIVES MAXIMUM BUSWAY FLEXIBILITY

Because Trumbull LVD FLEX-A-POWER® is made in pre-fabricated units, you save money with this system these three ways.

The units are easily and quickly put together . . . no special engineering skill is required for installation. This means that many expensive time and labor costs are eliminated for a *lower "installed cost."*

Not only is LVD pre-fabricated, but it is pre-engineered so that you can predetermine electrical performance before actual installation. This advantage is an important factor in minimizing voltage drop and in keeping machine efficiency high.

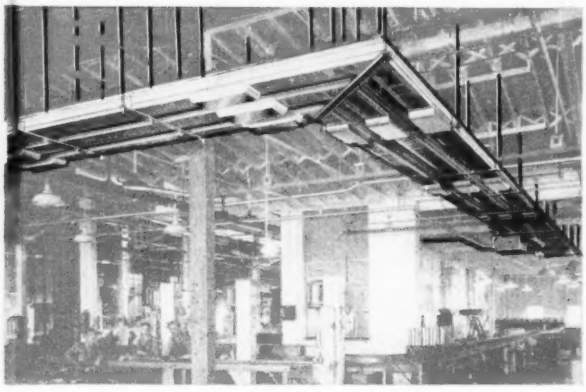
LONG-LIVED MATERIALS —

Another advantage — LVD FLEX-A-POWER materials do not deteriorate even under the most severe operating conditions, thus assuring years of satisfactory service *without costly maintenance repairs.*

ADAPTABLE, "TAKE-APARTABLE" —

LVD FLEX-A-POWER is readily adaptable to any power distribution problem you may have. Fast to install, its convenient "take-apart-ability" allows you to relocate your LVD system without replacing a single part!

Learn more about the many advantages of LVD. Write for Circular TEC 152 today. THE TRUMBULL ELECTRIC MANUFACTURING COMPANY, Plainville, Conn.



Men Who Observe the Best Electrical Practice Make It a Practice to Use

TRUMBULL (T) ELECTRIC

TRUMBULL'S TRAINLOAD OF NEW PRODUCTS

Anaconda continues its "Wire Ahead" Campaign to your industrial customers. They are reading this ad now.

But what about the DISAPPEARING ACT *in your plant?*

You might be even more mystified to discover just how much of the electric power you pay for isn't there when it gets to the machines. It's the black magic of overloaded, over-extended, obsolete wiring* that slows down motors and men.

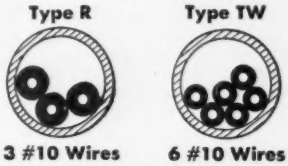
Your plant power engineer, consulting engineer, electrical contractor or utility power salesman knows how to materialize your vanished power. Better ask . . . *soon.*

***WIRE AHEAD** . . . a comprehensive discussion of preventive maintenance, points out the symptoms of inadequate wiring, presents detailed plans for anticipating electrical demand. Forty-eight factual pages of practical information and suggestions free on request.

Densheath Type TW Building Wire with its special thermoplastic insulation is sound production insurance in any plant. It will not support combustion, is long-aging, impervious to acids, oils and alkalis. It is recognized by the National Electrical Code for circuits up to 600 volts and temperatures up to 140° F. . . . and for wet and oily locations. Being light weight, with a smooth, slick finish and without braid, Densheath pulls through easier . . . resists abrasion. Permanent, bright colors for quick circuit identification. Write for literature.

This is important, too—*for rewiring in existing raceways,* the Code recognizes the smaller diameter of Densheath TW and permits more conductors to be pulled in the same size conduit. Below, a typical case—

½" CONDUIT



ANACONDA

ANACONDA WIRE & CABLE COMPANY

25 Broadway, New York 4, N. Y.

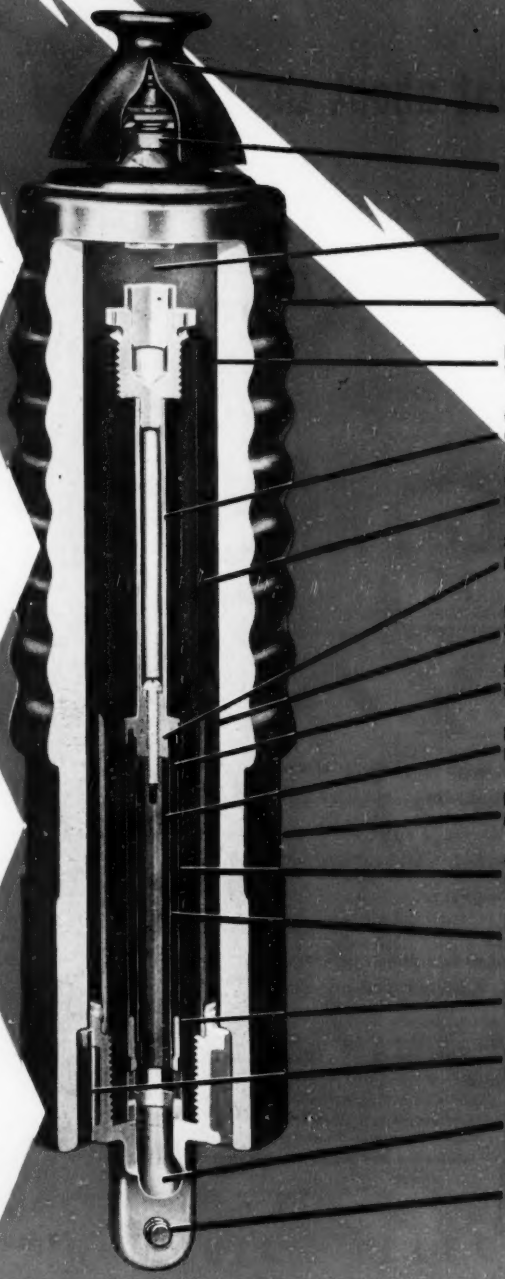
NEW—AN OUTSTANDING

No Line Lockouts are assured because of enclosed series gap; this also assures consistent operation of the arrester since it is unaffected by sleet, snow or other conditions that may affect an exposed series gap.

Keystone Expulsion Arresters embody to the fullest possible extent not only the recognized fundamental principles pertinent to arresters of this type, but also new concepts of design and construction which make them outstanding examples of the modern expulsion arrester.

Parallel Discharge and Deionization Paths provide very high surge discharge capacity combined with limitation and fast interruption of follow current flow irrespective of system capacity, thereby assuring long life and continued efficient operation of the arrester.

Ventilation of Body through multiple vents in the base seal assures that the interior of the body will be dry at all times. Vent passages also provide outlets to atmosphere for arc gases generated in series gap during operation.



KEYSTONE ARRESTER

LIGHTNING ARRESTER

OF THE EXPULSION TYPE

THE "KEYSTONE ARRESTER"

BACKGROUND—The Keystone expulsion type lightning arrester is not merely another lightning arrester of the expulsion type, but is one which has been developed by, and which embodies the wide technical and practical experience of, a Company which for some 57 years has specialized in the design and manufacture of many types of highly efficient lightning protective equipment.

ADVANCED CONSTRUCTIONAL FEATURES—In addition to many constructional features clearly shown in the illustration on the opposite page and briefly described, additional comment is warranted on two of the major ones:

1—*The Enclosed Series Gap.* 2—*Parallel Discharge Path.*

These, either alone or acting together, are responsible for the following desirable characteristics of the Keystone expulsion arrester.

a—***Protective Characteristics***—these are excellent and provide a wide factor of safety between the impulse characteristics of the arrester and the demonstrated impulse strength of transformer insulation. This condition obtains throughout a wide range of applied impulse voltages and discharge characteristics.

b—***Surge Current Carrying Capacity***—is very high; these arresters will safely withstand surge current far in excess of the present standard test value of 65,000 amperes of approximately 5 x 10 microsecond wave shape.

c—***Follow Current Flow and Interruption***—is facilitated by the parallel discharge path; due to lesser follow current per path, fibre erosion is small and a long useful life of the arrester is thereby assured. Limitation of the follow current, irrespective of system capacity, is effected to a marked extent by this construction, thereby greatly assisting in its rapid interruption.

d—***The Low Arc Resistance***—in the parallel discharge paths in addition to limiting follow current flow also prevents to a marked extent the complete chopping of the voltage wave impressed across transformer insulation, thereby reducing the deleterious effects which rapidly chopped waves have on such insulation.

e—***Line Lock-outs*** cannot be caused by a failure of the arrester due to its enclosed series gap which has a 60-cycle sparkover voltage considerably higher than the line-to-ground voltage rating of the arrester.

f—***No Leakage Current*** can flow through the fibre arc-quenching element; this eliminates the possibility of burning or charring the fibre parts of the element which might occur if they were subjected to continuously applied line voltage.

g—***No Radio Interference***—because of the enclosed series gap and other features of design and construction the radio influence voltage of these arresters is of a very low order.

KEYSTONE expulsion arresters meet all requirements of ASA, AIEE and NEMA Standards for distribution expulsion type arresters.

Further information and bulletin sent upon request.

KEYSTONE Expulsion Type lightning arresters are offered in addition to our well-known and widely-used "Crystal Valve" valve type lightning arresters and do not supersede this line. Research, development, production and sale of the Crystal Valve Arresters will be vigorously continued as has been our policy since its introduction some 23 years ago.

ELECTRIC SERVICE
MANUFACTURING COMPANY
1709 CAMBRIA STREET PHILADELPHIA 32, PA.

G & W GROWS WITH A GROWING INDUSTRY*

Your particular electric distribution problems are of utmost interest to us.

Since 1905, when this company was founded, and when the original G & W disconnecting potheads were first developed, we have specialized in manufacturing cable devices for electric distribution.

Today, whatever your needs in this field may be, we will appreciate the opportunity to sit down and discuss them with you. If we can't help you, we'll tell you so. But the chances are very great that somewhere in the 44 years of experience G & W engineers have accumulated, you will find the answers to your problems.

You can continue to look to G & W Electric Specialty Co for:

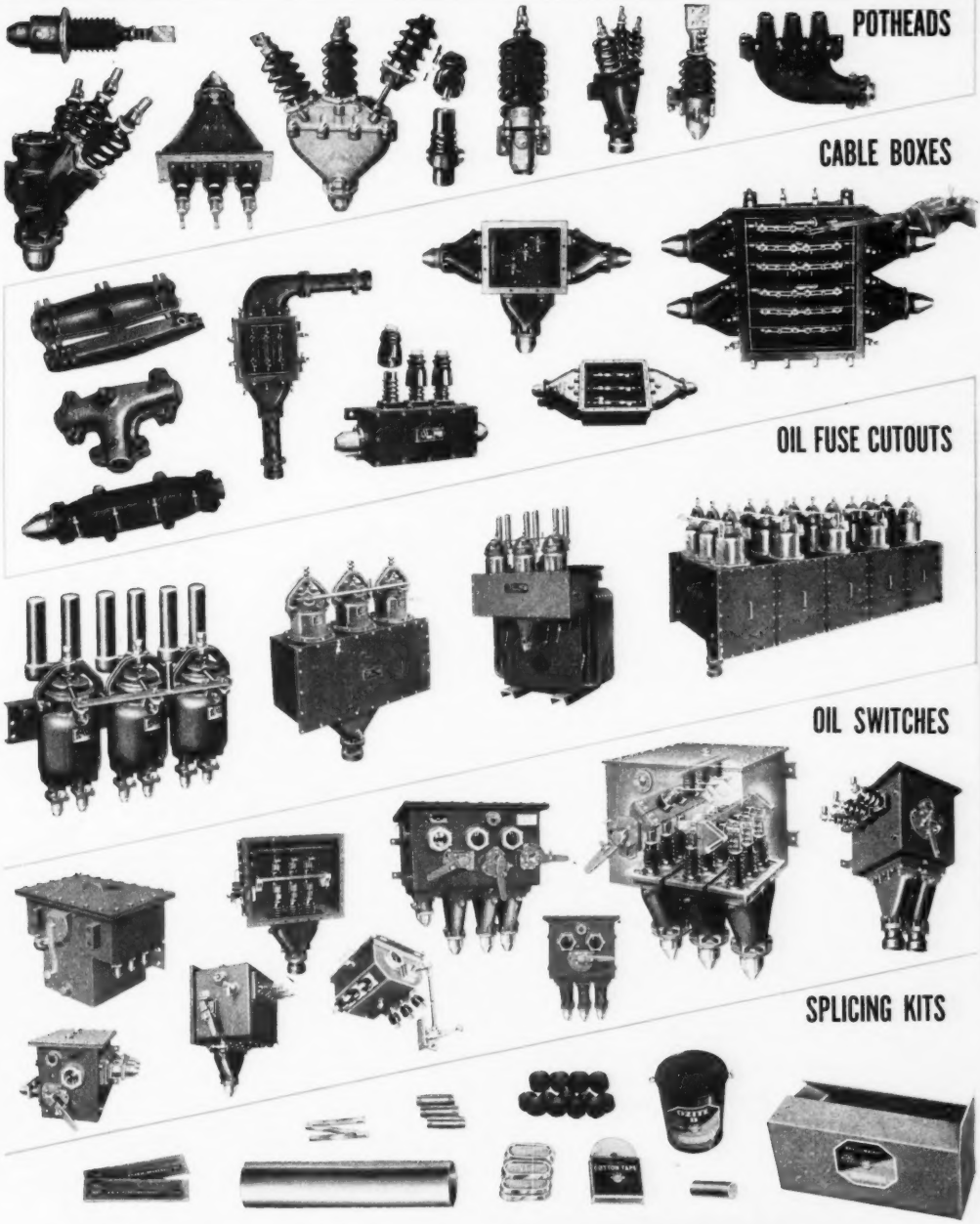
1 — Close technical cooperation on cable terminating, sectionalizing and splicing problems.

2 — High quality, economical products with advanced engineering features and simplified designs.

Write us or our representatives — there's no obligation.

* *44 Years of Specialized Electrical Manufacturing Experience...to help YOU!*

G & W PLANT...ENLARGED 1948



G&W ELECTRIC SPECIALTY CO.
7780 DANTE AVENUE CHICAGO 19, ILLINOIS
In Canada, POWERLITE DEVICES, Ltd., Toronto
G&W ELECTRIC SPECIALTIES
Potheads • Boxes • Oil Fuse Cutouts • Oil Switches • Splicing Kits

ANNOUNCING ANOTHER OKONITE

OKOLITE-OKOPRENE "Line-Tap" AERIAL CABLE

The only self-supporting cable design that can readily be Tapped Hot!

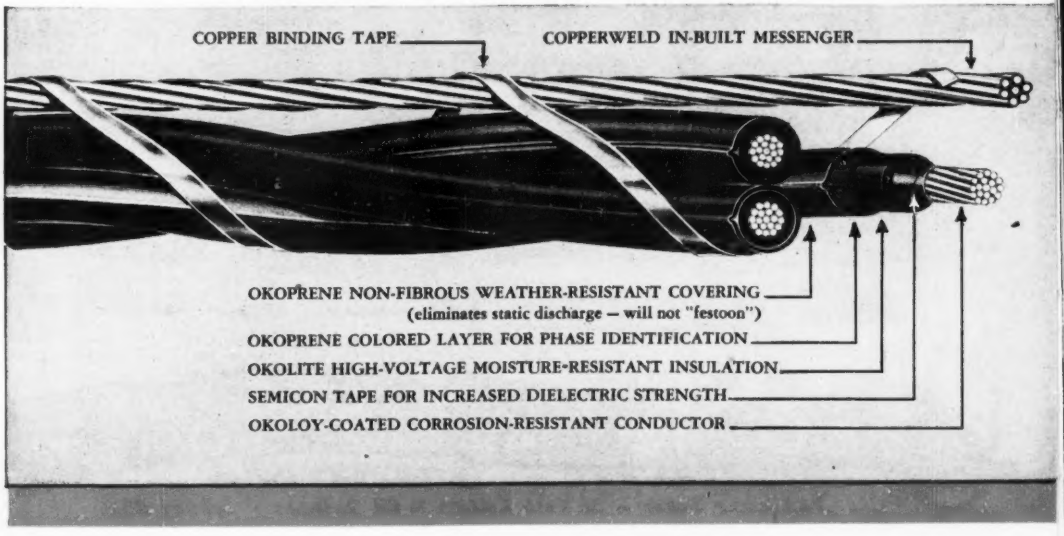
Here is what overhead distribution engineers have wanted: a self-supporting aerial cable that can be tapped hot — like weatherproof wire — by regular line crews.

Only Okolite-Okoprene "LINE-TAP" cable has this feature which has been made possible by the new "Dualay" method of assembly.* "Dualay" consists of twisting together self-contained Okolite-Okoprene conductors so that the direction of lay is reversed at regular short intervals, as shown in the sketch on the next page.

The opening up of the cable can be accomplished at the time of installation *without cutting a conductor or without performing any operation on messenger* — or later whenever the need arises for making a tap. The complete cable is so simple that any line crew can install it and make taps, splices and terminations without having to learn any special skills. A 5000-volt Okolite-Okoprene "LINE-TAP" aerial cable is as easy to splice as an ordinary rubber-covered wire.

In addition to this much-needed hot tap feature, Okolite-Okoprene aerial cables have many further

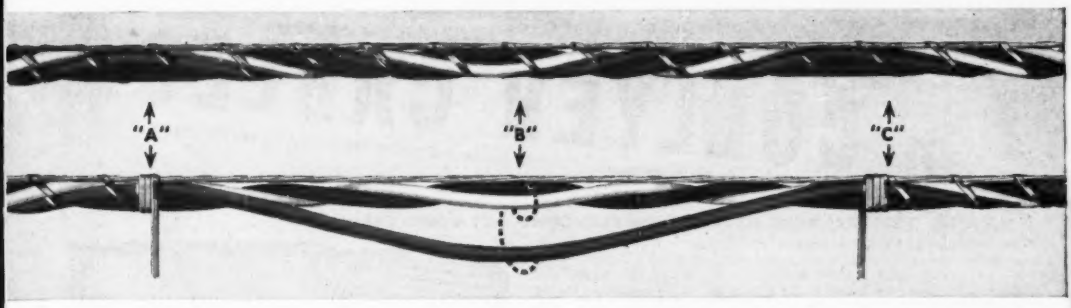
*Patent applied for


COPPER BINDING TAPE
COPPERWELD IN-BUILT MESSENGER
OKOPRENE NON-FIBROUS WEATHER-RESISTANT COVERING
(eliminates static discharge — will not "festoon")
OKOPRENE COLORED LAYER FOR PHASE IDENTIFICATION
OKOLITE HIGH-VOLTAGE MOISTURE-RESISTANT INSULATION
SEMICON TAPE FOR INCREASED DIELECTRIC STRENGTH
OKOLOY-COATED CORROSION-RESISTANT CONDUCTOR

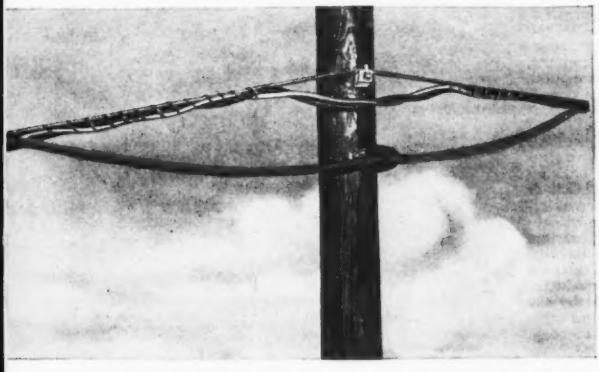
advantages not possessed by other types of self-supporting cable. Some are listed below.

Any Okonite salesman will be glad to show you how "LINE-TAP" cables can provide solutions to many of your aerial distribution problems and, at the same time, reduce labor and material costs.

Communicate with our nearest office today for the data that will convince you that your 1946 construction program should include at least one installation of Okolite-Okoprene "LINE-TAP" self-supporting aerial cable, or address your letter to The Okonite Company, Passaic, New Jersey.



(*Upper sketch*) A, B, and C are points where twist is reversed by "Dualay" method of cabling. When ready to make a tap, the binder tape is cut at B and wound back toward A and C and fastened. The conductor to be tapped (red) is untwisted and, as it straightens out, gains the slack taken up in the original "Dualay" cabling operation. (For clarity in the diagram the normally black conductors are shown in color.)



Making a single-phase — or three-phase — tap is simplicity itself with Okolite-Okoprene "LINE-TAP" cable. As shown here, the cable has been permanently supported by its in-built messenger which is secured by a fitting on the pole. The metal binder tape has been removed for a short distance on either side of the pole and the conductor about to be tapped has been untwisted and secured to a standard pin insulator. The binder tape is replaced over the conductors not being tapped. NOTE the ample separation obtained for working the cable hot.

Desirable Features and Advantages of Self-Supporting Aerial Cables

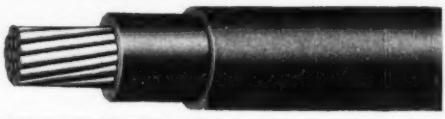
1. Reduce or eliminate tree trimming.
2. Overlength poles not needed to clear tree tops.
3. Fewer service interruptions or outages.
4. Reasonable cost.
5. Good appearance.
6. No messenger rings required.
7. Eliminate "bowing" and ring cutting.
8. Simple to install.
9. Light weight.
10. Long spans.
11. Less congestion on poles.
12. In-built messenger serves as neutral.
13. Reduce clearance space near buildings and other structures.
14. Grade clamps not required.
15. Greater reliability in storms — can operate even if poles are down.
16. Eliminate lead sheath troubles.
17. Eliminate lead sheath splices and wipes.
18. Reduce items purchased and stocked.

OKONITE insulated wires and cables

There's a World of QUALITY in COLLYER CABLES

SUPRENE (TYPE RR) NON-METALLIC UNDERGROUND NETWORK CABLE

Moisture-resistant rubber insulation and neoprene jacket. Insulation provides exceptionally good electrical properties for efficient power delivery, safeguarded against destructive action of chemicals, oils, moisture, and abrasion by specially designed, tough neoprene jacket. Ideal for aerial or underground service. Approved by the Underwriters as Type USE for direct burial in the earth or in ducts. Available in single or multi-conductor construction in all sizes.



NEUTRAL SUPPORTED OVERHEAD SERVICE CABLE

Two insulated power conductors cabled spirally around the bare neutral conductor — a hard drawn copper messenger. Messenger, if local conditions require, may be covered with $\frac{3}{64}$" neoprene jacket compound, and may be of Copperweld for greater strength and longer spans. Available in two types:

1. Insulated conductors individually covered with Performance Grade synthetic rubber compound to ASTM Spec. D-755, and protected by a jacket of neoprene to ASTM Spec. D-752.
2. Insulated conductors covered with single layer of neoprene, combining insulation and protection in one jacket compound. This type is lighter in weight and lower priced than type 1.

SELF SUPPORTING AERIAL CABLES

In single conductor and three conductor constructions for two general voltage classes: 600 V. and 5000 V. Single conductor sizes #6 through #1; three conductors #6 through #500 MCM. Collyer insulation of Oil Base Ozone Resisting Compound meets all requirements of ASTM Spec. D-574 and IPCEA Standards. Jackets of neoprene meet ASTM D-752 . . . have high resistance to abrasion, sunlight, and weathering . . . and low surface leakage characteristics. Copperweld messenger for single conductor has current carrying capacity at least equal to the power conductor. For three conductor cables, the size Copperweld messenger is usually specified by the customer to suit his particular requirements. Messenger and cable are pre-assembled at our factory, and bound together by a strong, flat copper tape.

POLYETHYLENE NYLON TREE WIRE

The combination of Polyethylene insulation of tremendous electrical strength and Nylon jacket of great toughness produces the ideal Tree Wire for the wear and tear of suburban distribution service. The abrasion resistance of Nylon, as determined by du Pont Abrader Tests, is rated over four times greater than that of a high grade neoprene jacket. Nylon is also unusually resistant to natural weathering. Nylon has unusually high resistance to longitudinal surface leakage — over two million megohms measured between metal bands one inch apart! "Tracking" is minimized. A flash-over of twenty thousand volts between metal bands one inch apart leaves no path of carbon on the surface of the Nylon.

Write today for complete specifications and samples of quality-built Collyer Cables.

Collyer **INSULATED WIRE CO.**

245 ROOSEVELT AVE., PAWTUCKET, R. I.

THE "NON-DAMAGEABLE" FUSE LINK

In 7- to 200-ampere S & C Fuse Links, the "non-damageable" feature results from the solderless-jointed fusible element of pure silver, a metal which has low fusion-time to melting-time ratio, and during fusion—short of actual severance—does not change cross-sectionally; also from the helical coil construction which precludes corona corrosion, and permits sudden thermal expansion without damaging stresses.

Even the smallest S & C Fuse Link is never "damaged" by lightning or other high current surges that may happen to raise the temperature of the fusible element to a point within the melting range but short of complete fusion (severance). It is not subject to corona and corrosion, and not impaired by vibration, abrasion, and strain incidental to ordinary handling or application conditions.

This "non-damageable" nature of the S & C Fuse Link insures permanence to the accuracy of time-current characteristics, which in turn permits "balanced" distribution transformer fusing, i. e., equal and judicious consideration to:

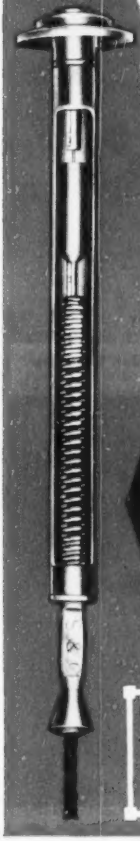
(a) ***Close, permanently reliable coordination*** **with primary sectionalizing and secondary protective devices;**

(b) ***Adequate secondary short circuit protection*** **for transformers;**

(c) ***Minimization of unnecessary fuse blowings*** **from transient faults and lightning surges.**

In addition, the "non-damaging" feature precludes any necessity for replacing "suspect" fuses after high current surges.

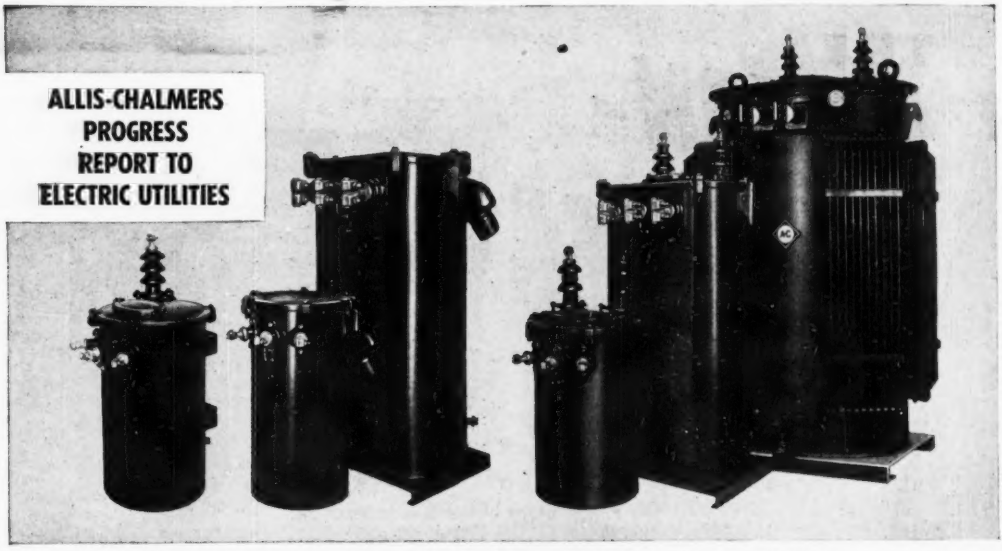
For several years these important advantages have been appreciated by a constantly increasing number of the larger electric utilities. Bulletin 218-B tells more of the story.



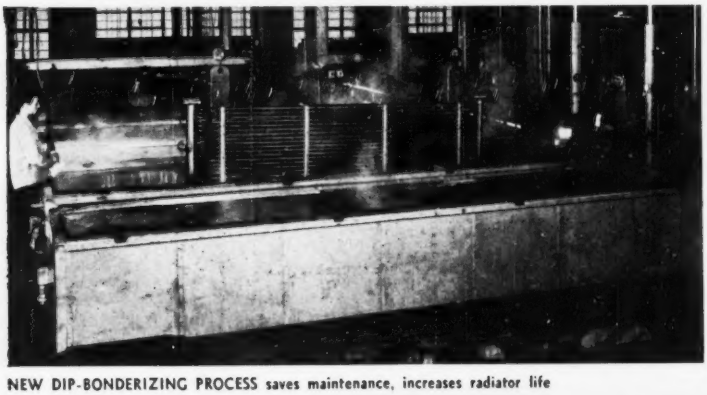
In 1- to 5-ampere S & C Fuse Links, the "non-damageable" feature is secured from a corona-shielded, high resistance, solderless-jointed fusible element which resists electrical, mechanical, and chemical deteriorating influences, and is held under *non-additive* pretension permitting rupture at a temperature lower than that where marked elongation could take place—also nullifying tension variations imposed by cutout.

S & C ELECTRIC COMPANY
4421 Ravenswood Avenue
Chicago 40, Illinois, U. S. A.
Formerly SCHWEITZER & CONRAD, INC.

ALLIS-CHALMERS PROGRESS REPORT TO ELECTRIC UTILITIES



ALL RATINGS AND DESIGNS of distribution transformers listed in Fourth Report, EEI-NEMA are offered by Allis-Chalmers



NEW DIP-BONDERIZING PROCESS saves maintenance, increases radiator life

PROTECTED "ACP" dist. transformer

NEW BUSHING cuts tank heights as much as 3 inches

NEW TESTING FACILITIES ensure on-the-line performance

Distribution, Instrument Transformer Production Stepped-up

ALLIS-CHALMERS' Pittsburgh Works, which produces, in addition to Power Transformers, all "A-C" Distribution and Instrument transformers has completed an expansion and standardization program which maintains its position as one of the leading transformer plants in the country.

Added to a complete new plant, many new facilities and processes have been introduced. Examples: A new core steel plating machine which produces a coating superior to flash varnish finishes. A new infra-red drying tunnel. Additional bonderizing equipment to handle surfaces of all fin-type radiators. New electric annealing furnaces enabling closer control. And new resistance welding machines for welding distribution transformer tanks.

★ ★ ★

DISTRIBUTION TRANSFORMERS. Soon to come off A-C production lines will be a new line of completely protected type "ACP" distribution transformers. Standard ratings to 50 kva in standard voltages will follow.

Many ratings of conventional distribution transformers in line with the Fourth Report of EEI-NEMA are now being built . . . all sizes will be in production by the middle of this year. Round tank construction has been extended from 25 kva through the 50 kva size thereby reducing weight and dimensions on these ratings.

New "Bent Contour" high voltage bushings now available eliminate high voltage pockets, reduce tank heights up to 3"

Rural Distribution Transformers type "RU" with tank mounted combination lightning arrester and cutout are available; an economical type of self-protection for users operating rural lines.

Network Transformers, now designed to fit into any system requirements, incorporate an improved disconnect and grounding switch and housing, both smaller and welded to the tank. To eliminate a possible point of leakage, tap changer stuffing box is replaced by pipe plug and removable handle for operation through main cover.

Under development are new lines of silicone-insulated transformers for marine service, up to 100 kva; and silicone insulated, totally enclosed explosion-proof transformers for the petroleum industry. *Significance:* A-C will offer, at an early date, silicone-insulated transformers to the commercial market.

★ ★ ★

INSTRUMENT TRANSFORMERS. Production is steadily gaining on these critically needed transformers.

Rounding out the line, a new low voltage, 600 volt, current transformer for indoor metering is now available. It has a single primary and single secondary with accuracy suitable for one or two watt-hour meters. Maintains accuracy at 50% overload without out overheating.

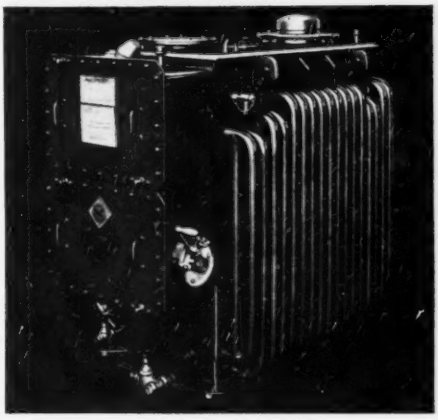
A smaller, safer terminal board for indoor dry-type current transformers has been developed. And the need for a low pf, small, oil-tight, economical secondary stud bushing has been met with a molded bushing, better electrically and mechanically than former units.

★ ★ ★

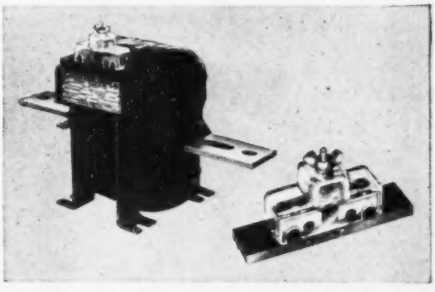
At Allis-Chalmers Pittsburgh Works and throughout other A-C plants, millions of dollars have been spent improving and increasing plant facilities . . . developing new production methods to build *better* electrical and industrial products for you. As your plans for expansion take shape, feel free to call on the expert equipment recommendation offered by your nearby A-C Sales office. ALLIS-CHALMERS, 932A S 70TH ST., MILWAUKEE 1, WIS.

A2719

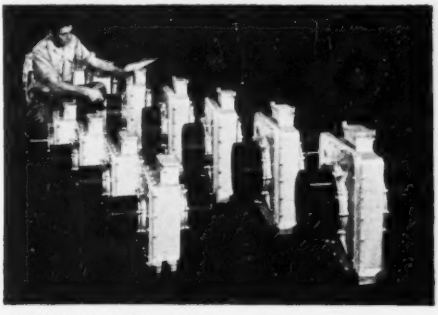
NEW PITTSBURGH "COLUMBUS" PLANT houses core-steel, radiator, steel-cutting, winding processes



NETWORK TRANSFORMER improvements reduce dimensions



KLW 600 V indoor current transf., transparent terminal cover



TYPE BKAW-1 DRY-TYPE indoor current transformers

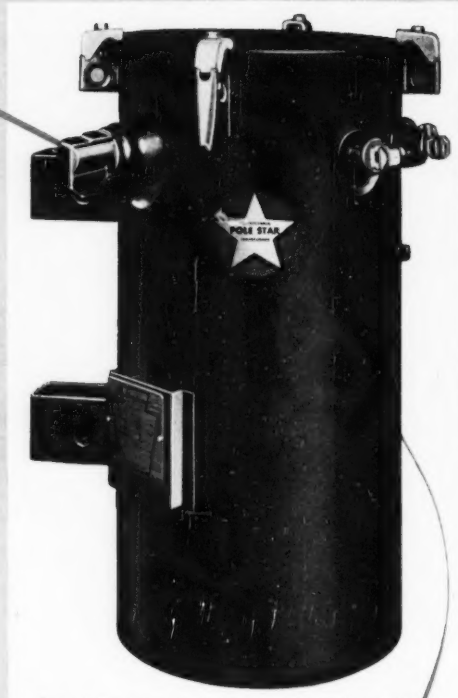
ALLIS-CHALMERS

Pioneers in Power and Electrical Equipment—Builders of the World's Widest Range of Major Industrial Equipment!

NO POCKETS
ON THE
POLE STAR *

Terminals receive line leads at the same angle as pocket-type bushings. Solderless connectors are forged of naval brass to assure a rugged connector of uniform strength. Heavy bakelite insulating caps are secured to the solderless connectors by spring wire hinges.

Caps are self-supporting above the terminals. Line connections are made with a standard wrench. Solderless connectors are completely exposed so lineman can see the connection he is making. Caps are closed by hand pressure and completely cover bushing terminals.



Embodying a new wound core design with an inherent low exciting current, Pole Star Transformers are made in sizes 25 Kva and below, 14400 volts and below, single phase, 60 cycles, OA, conforming to E.E.I.-NEMA Standards. Will soon be available in sizes up to 100 Kva.

Years ago, when bushings were neither weatherproof nor leakproof, pockets and pocket bushings were required on Distribution Transformers. In designing the Pole Star Transformer, however, Pennsylvania Development Engineers replaced the high voltage pockets and pocket bushings with sturdy, streamlined sidewall bushings. This was done because today bushings are provided with stud-type terminals and gasket seals which insure pressure tight joints and sealed tank construction. This is another one of the modern improvements incorporated into the Pennsylvania Pole Star Transformer. It is another example of Pennsylvania's Engineering Ingenuity.

** P. S. Let the Pole Star be your guide.*

If you want to know more about the Pole Star Transformer, write to us for Catalog No. 349.

Pennsylvania
TRANSFORMER COMPANY
PITTSBURGH, 12, PENNSYLVANIA

ORCHIDS TO YOU, ELECTRICAL WORLD, ON YOUR 75TH ANNIVERSARY

In Utility Equipment

Performance is the Payoff

and KEARNEY Products Give You Performance *Plus*

KEARNEY TRIP-OUT

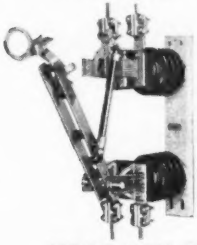
16 Years' Service

Millions of switch-years testify to the unfailing and continuing capacity of the Trip-out. Noted for its high rupturing capacity derived from a combination of two features, the Kearnite fibre fuse tube and the open upper end fuse cartridge, the Trip-out is used for tough assignments in ratings through 69,000 Volts and 200 Amperes.

KEARNEY TRIP-O-MATIC

15 Years' Service

Since the original Trip-o-matic was introduced 15 years ago, there have been twenty-one distinct, improved modifications — an example of the continuing research of Kearney Engineers and the progressiveness of the company. Trip-o-matics give you up-to-the-minute advantages of modern cutouts and are available in 5,000 and 7,500 Volts, 50 and 100 Ampere ratings.



KEARNEY REGULATOR BY-PASS SWITCHES

10 Years' Service

Safe switching sequence is *automatic* when you use Kearney Regulator By-Pass Switches. Pull one switch ring — the main line is by-passed, both leads to the regulator are opened, and the exciting current is safely interrupted, all in one quick, safe operation. Restoring the regulator in service is a simple matter of reclosing the By-Pass Switch as you would any disconnect switch.

KEARNEY SHUNT CAPACITORS—*1 Year Service*

The newest member of the Kearney group of quality products is the Shunt Capacitor for power factor correction and the conservation of power that would otherwise be unavailable. These capacitors are packed with an exclusive Kearney protective packaging feature that assures undamaged installation. Write for Bulletin 21-1 for complete information.

JAMES R. KEARNEY CORPORATION · 4224-42 Clayton Ave., St. Louis 10, Mo.

Canadian Plant: Guelph, Ontario

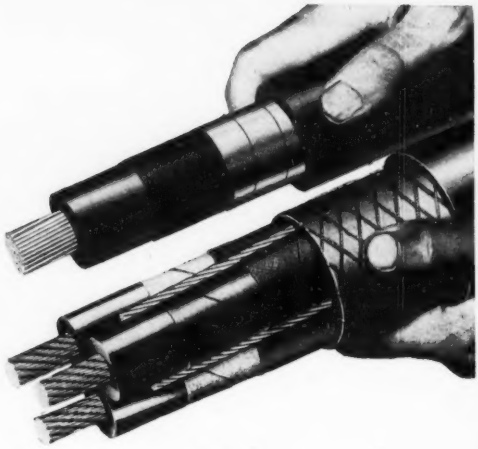
-134

Always Specify JAMES R. KEARNEY CORPORATION ST. LOUIS, MO. *for the Job . . .*

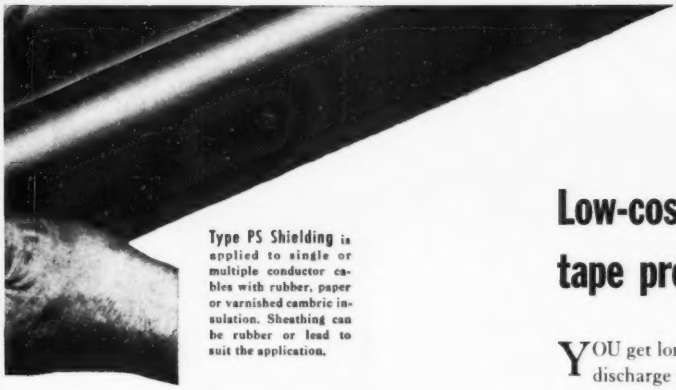
Better Construction — *SAFER* Maintenance

PS SHIELDING

(U. S. Patents 2,322,702 and 2,446,387)



eliminates Corona cutting in



Type PS Shielding is applied to single or multiple conductor cables with rubber, paper or varnished cambric insulation. Sheathing can be rubber or lead to suit the application.

power cables

Low-cost conducting rubber tape proves highly effective

YOU get longer trouble-free life plus elimination of static discharge when Type PS Shielding is used on rubber insulated cables operating at over 2000 V. For rubber cables this low-cost shielding consists of a fibrous tape coated with conducting rubber, vulcanized to the surface of the insulation. Such a tape may be used over the stranded conductor for protection against internal corona and over the outer surface in contact with the usual shielding tape, ground wires or conducting sheath. The tape eliminates any air gaps between insulation and conducting element as it becomes bonded to the insulation during vulcanization.

Type PS Shielding remains flexible . . . is superior to metal shielding which tends to separate slightly from the insulation when the cable is bent and straightened. This forms air gaps . . . causes a spark discharge with corona and ozone formation.

Type PS Shielding with conducting rubber is a development of the American Steel & Wire Company. It proved so successful that other cable companies have been licensed to use the same construction. The main applications are for portable power cable, for aerial distribution lines, and for heavy power cable wherever voltage discharge will cause damaging corona and television interference.

The safety features of the grounded tape make PS Shielded Cable ideal for use in mines and other hazardous locations. PS Shielding has been applied to both single and multiple conductor cables which are sheathed to meet various applications. Write for complete information.

AMERICAN STEEL & WIRE COMPANY, GENERAL OFFICES: CLEVELAND, OHIO
COLUMBIA STEEL COMPANY, SAN FRANCISCO, PACIFIC COAST DISTRIBUTORS
TENNESSEE COAL, IRON & RAILROAD COMPANY, BIRMINGHAM, SOUTHERN DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

American Electrical Wire and Cable

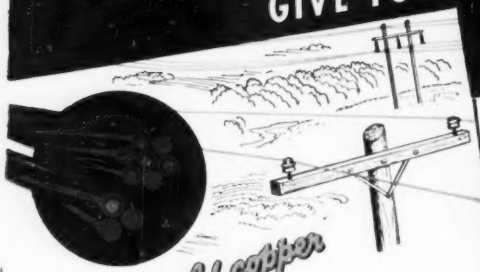
UNITED STATES STEEL

THESE Copperweld PRODUCTS GIVE YOU - -

TRADE MARK

THE CONDUCTIVITY AND PERMANENCE OF COPPER

plus THE RUGGED STRENGTH OF ALLOY STEEL



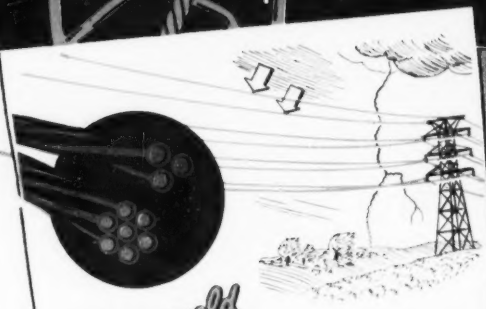
Copperweld-copper

POWER CONDUCTORS

Copperweld-copper power conductors possess the strength and safety required for long span construction. Their ruggedness permits them to withstand heavy ice and wind loads as well as other emergency conditions not always considered in the original design of the line. Their high conductance is a known factor. Long life is assured because each wire is permanently protected against corrosion.

GRIP-FLEX[45] INSULATOR TIES

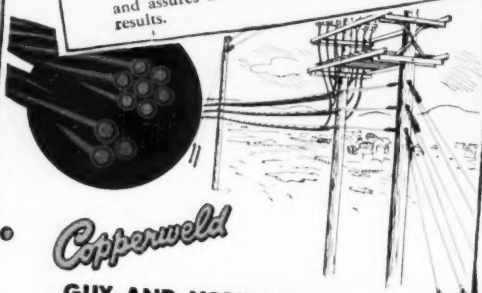
This preformed tie is simple in design and easy to install. It is a distinct improvement over the hand-wrapped tie. Takes less time to apply—develops greater holding power — increases conductor life — and assures uniformly good results.



Copperweld

OVERHEAD GROUND WIRE

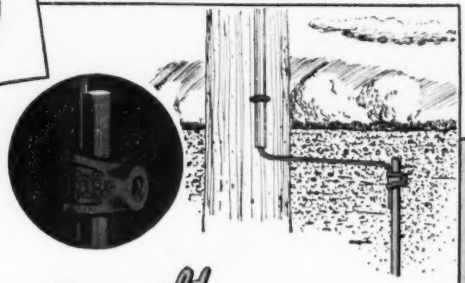
Copperweld non-rusting overhead ground wire provides safe, efficient and economical protection for power transmission lines. Its high strength permits small sags with ample mid-span clearances. Since Copperweld is non-rusting, its high strength is permanent—making it the ideal overhead ground wire.



Copperweld

GUY AND MESSENGER STRAND

Buy Copperweld Strand to the exact strength you need—it is not necessary to provide excess strength as insurance against rusting. Copperweld can't rust because the high strength steel core is permanently protected by a thick covering of copper which will not crack, peel or flake.



Copperweld

GROUND RODS AND CLAMPS

By using Copperweld Ground Rods and Clamps, corrosion and high resistance contacts are eliminated. All contacts are copper-to-copper. The stiff steel core insures easy driving and is permanently protected from rusting by a thick covering of copper. This rod, with a rugged one-piece clamp, makes a simple and dependable ground connection.

use Copperweld

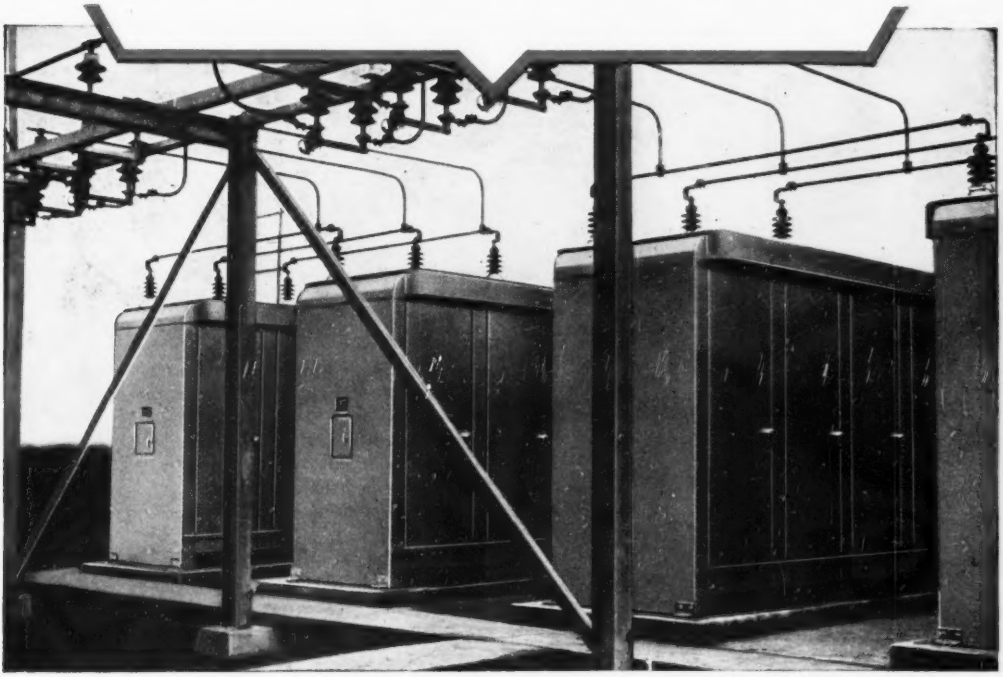
COPPERWELD STEEL COMPANY GLASSPORT, PA.

SALES OFFICES IN PRINCIPAL CITIES

New Capacitor Equipments

using 25-kvar capacitors

Cut Installed Cost



This is one of the largest installations of capacitor equipments made to date. It consists of General Electric 5100-kvar equipments of the newest design, employing 25-kvar Pyranol* capacitors with glass bushings.

General Electric has recently introduced a new line of power capacitor equipments using 25-kvar capacitors. Price of the equipment, including capacitors, is materially lower per kvar than those previously available. The housing is about 30% smaller, cutting foundation costs and saving space. And the number of individual capacitors is reduced 40%.

MANY IMPROVEMENTS TOO

Besides their lower installed cost and smaller size, these new equipments bring you several improvements that will interest operating personnel: The roof terminal bushings are arranged so as to simplify bus work, particularly where banks are used. Improved interlocking of doors with line breakers and grounding switches precludes possibility of reaching charged capacitors. Thermostatically-controlled fans provide air circulation within the housing when needed.

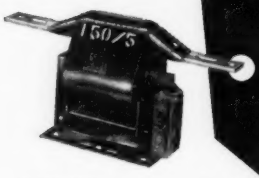
For information on these equipments, call your G-E sales office. *Apparatus Dept., General Electric Company, Schenectady 5, N. Y.*

*Reg. U.S. Pat. Off.

GENERAL ELECTRIC

407-16

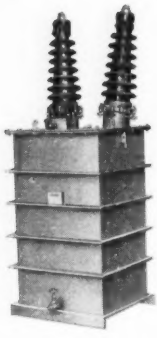
UPTEGRAFF transformers



CURRENT—Uptegraff Type CR Indoor Current Transformer. Stocks available for immediate shipments.

SPECIALTY—Specialty Transformers are built for cabinet or indoor service. Sizes: 0.1 to 10 KVA. Type E completely enclosed unit shown.

for every class of service

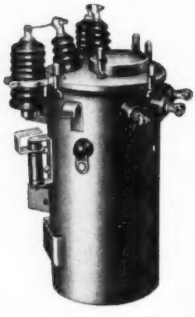


POTENTIAL—Uptegraff Potential Transformers are made in sizes up to 69,000 volts.

The dependability and economy of Uptegraff Transformers is proven by their service in installations of all types—power, distribution, instrument and specialty.

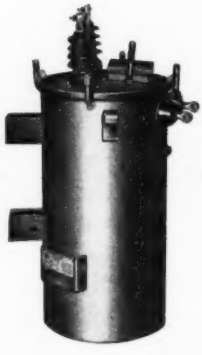
Uptegraff power transformers are made in sizes up to 10,000 KVA, 69 KV, for utility and industrial plant service, indoors or outdoors. Distribution transformers are made in liquid and air-cooled types, in sizes from 3 to 500 KVA. Specialty transformers include air-cooled and compound-filled types, specially designed and built to meet individual customer's requirements. A complete series of instrument and potential transformers rounds out the Uptegraff line.

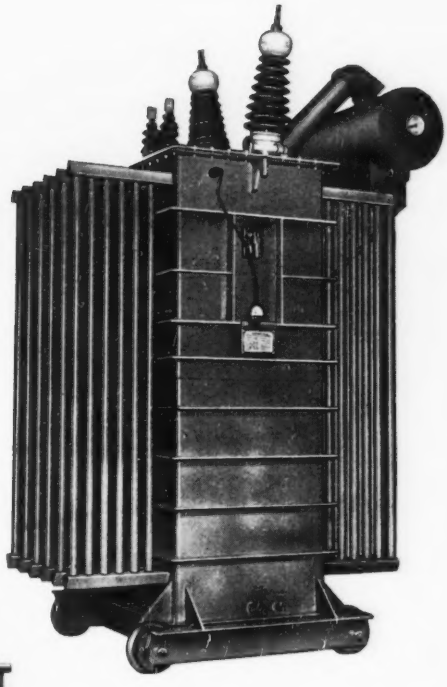
Quality construction and sound engineering designs assure the efficient, dependable performance of Uptegraff Transformers. We are prepared to give prompt service on units of standard or special design and construction.



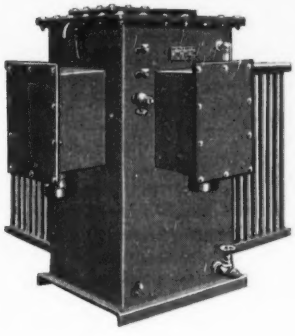
DISTRIBUTION

Distribution Transformers for pole mounting are made in all required sizes and ratings. Cover or pocket mounted high-voltage bushings as desired. Completely self-protecting type shown at left.





DISTRIBUTION—Large Uptegraff Distribution Transformers (below) are furnished for either outdoor or indoor service. Sizes, up to 69 KV Class.



POWER—Uptegraff Power Transformers are made in sizes to 10,000 KVA, 69 KV, for indoor or outdoor service. Oil or Askarel filled, sealed tank construction up to and including 2,000 KVA sizes. Structurally strong, electrically efficient, thoroughly dependable.

DRY TYPE—A complete line of Dry Type Distribution Transformers is offered by Uptegraff. Made with Class B insulation, in standard or special designs. Type DBT is shown here.

R. E. Uptegraff Manufacturing Co.

Scottdale, Penna.

Your own records will show what we've done about lightning

In the middle of 1943 our engineers made discoveries about impulse strength which led to changes in design of small, low- and medium-voltage distribution transformers. What these changes accomplished can be seen in *your* records.

If your experience is typical, roughly half of all distribution transformer failures can be charged to lightning. However—if your records are typical—on all Spirakore transformers delivered since late 1943, lightning failures have been almost insignificant.

One of Many Spirakore Advantages

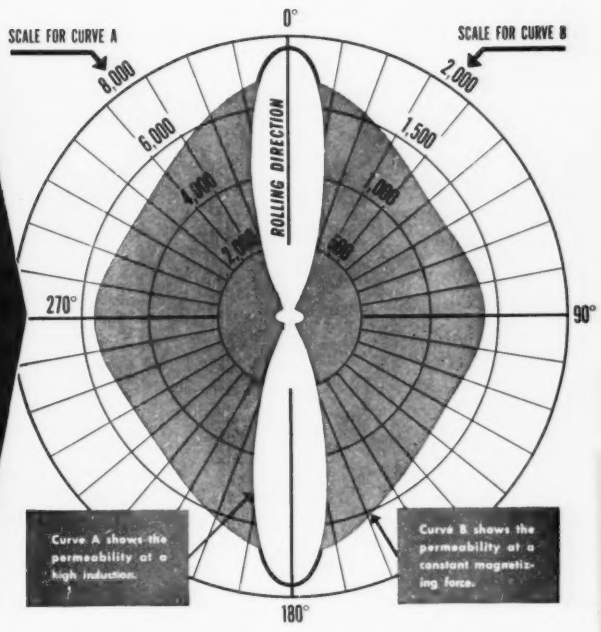
Important as this increased impulse strength is, it is still only one of the advantages you get with General Electric distribution transformers. You get Spirakore design throughout the entire line of single-phase liquid-filled transformers—with its great savings in size and weight. You get improved clamping construction for greater mechanical strength. You get sealed tanks for longer oil life. You even get a new, better, synthetic-resin baked-on paint which improves appearance and reduces maintenance.

Spirakore Still Leads

Today—as ten years ago when lighter, smaller Spirakore transformers made history—Spirakore still leads the field—the finest distribution transformer we have ever made, the finest you can buy. Ask for Bulletins GEA-4885 and GEA-4521. *Apparatus Dept., General Electric Company, Schenectady 5, N. Y.*

GENERAL ELECTRIC

THIS IS THE AGE OF ORIENTED ELECTRICAL STEELS



Working with the electrical industry has been a tradition since Armco first produced special silicon steels nearly a half-century ago. And never has this been truer than in the past 10 years, when ARMCO Oriented Electrical Steels helped bring about a new age of efficiency in transformer operation.

Electrical steel specialists at Armco are privileged to have pioneered in the development of these special grades. They are recognized as the most important forward-step in the electrical industry in many decades.

ARMCO Oriented Steels were the first fully annealed cold-reduced grades of oriented steels on the market. They have made possible the manufacture of lighter transformer cores with higher operating inductions. Designers have quickly recognized advantages of lower core loss concurrent with higher permeability in the rolling direction—also a higher space factor.

These are only a few of the special-purpose electrical steels produced by Armco since 1903. And as in the first half of the century, Armco will continue to team up with technicians of the electrical industry to make possible better steels for better electrical equipment. Armco Steel Corporation, 266 Curtis Street, Middletown, Ohio.

Export: The Armco International Corporation

ARMCO

ARMCO ORIENTED STEELS

For

. . . specify

OLIVER
IRON AND STEEL
CORPORATION
South Tenth and Muriel Sts. · Pittsburgh 3, Pa.

a lifetime of dependable service

OLIVER POLE LINE MATERIALS

The long service life of Oliver Pole Line Materials saves money for the purchaser, and reflects credit upon the specifier.

In 1894, Oliver made the first Pole Line Materials used in America, in Pittsburgh, Penna., where the infant electrical industry was rapidly developing.

Constant improvements have been made in designs and manufacturing facilities, keeping pace with the advancing requirements of the electrical industry. All steel products for outdoor service are hot dip galvanized. Today the name Oliver stands for the best, most modern and most complete line of Pole Line Materials. Representative items are shown below; the complete line, which consists of hundreds of items, is described in Oliver Catalog No. 43.

You make no mistake when you specify OLIVER!

From the Complete Line of OLIVER Pole Line Materials

INSULATOR PINS

Oliver offers all types and sizes of Insulator Pins, including Wood-Top, Forged Steel, Pole Top, Transformer, Neutral Crossarm, Wide Base, Corner and other types of pins. Available in many styles for wood or steel crossarms.

CLEVISES

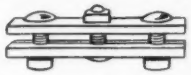
For every requirement of dead-ending or other service, Oliver Clevis styles include: swinging fork, tongue and thimble, strain and many others. All sizes. Efficient and mechanically strong.

WIREHOLDERS

Oliver Wireholders are made with either stud bolts or wood screws. Designed so that, in service, the porcelain is in compression and the metal parts in tension. Strong and rugged. Smooth, rounded surface with heavy glaze to exclude moisture.

BRACKETS

The complete range of types and sizes of Oliver Brackets, includes: Transposition, Break Iron, Neutral, Extension, House, Swinging, Cross Arm Spreader and many others. For pole, crossarm, or other mounting; single or multiple wire.

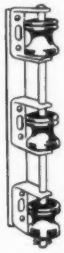


GUY CLAMPS

Two, three and four-bolt Oliver Guy Clamps, are made in light, medium and heavy types. Straight, smooth grooves offer greater clamping area and are not harmful to strands. Close tolerances assure proper seating and maximum holding power.

BOLTS

Bolts of all desired types and sizes are provided, including machine, eye, thimbleye, double arming, expansion, lag screw, carriage, U-bolts, and others. Also a complete line of nuts and washers.



SECONDARY RACKS

Serving every need, Oliver Secondary Racks include heavy, medium and light types in many styles and sizes. Strong, riveted construction, hot dip galvanized, made from new open hearth steel. Furnished complete with insulators unless otherwise ordered.

CROSSARM BRACES

Flat and angle Crossarm Braces are offered in many styles and sizes for all classes of service. Vertical and Alley Arm Braces are included.

Accurately formed and made.

ANCHORS

A recent addition to the line of Oliver Anchors is the new expanding anchor illustrated here. Compact, strong, easy to install. Expanded by pusher-arm principle. Other styles include screw and cone types.

OLIVER POLE LINE MATERIALS

Produced continuously and constantly improved - since 1894

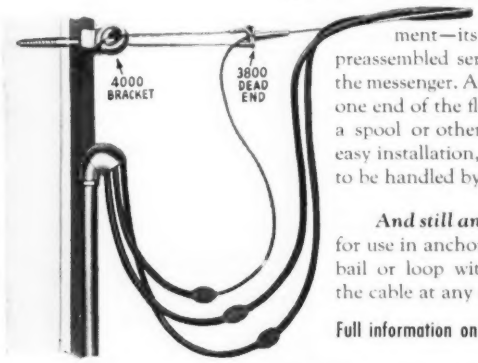
25 Years of Usable Development

Electroline finds particular cause for pride in its record of having originated and developed many vital improvements used in power transmission and distribution.

Electroline's development of solderless connectors, automatic line splices, dead ends and kindred items has made possible the broader use of hard drawn copper and higher strength conductors. The economies resulting from the use of Electroline devices and longer span construction has brought the blessing of electricity to remote rural communities as well as urban areas.

Following major disasters with their widespread destruction, Electroline products have made it possible to restore electric service within hours instead of weeks—and at a fraction of the previous cost.

Now Another Special—**Electroline's NEW Service-Drop Automatic Dead End**
for use with preassembled messenger-supported cable



Electroline presents another new development—its series 3800 automatic dead end for supporting preassembled service cable using a bare neutral conductor as the messenger. Assembled as a one-piece unit, this dead end has one end of the flexible bail detachable for installation around a spool or other supporting anchorage, permitting quick and easy installation, with only one part, other than the conductor, to be handled by the lineman.

And still another by Electroline is the 4000-series bracket, for use in anchoring service drops, permits insertion of a closed bail or loop without opening the loop and securely supports the cable at any angle.

Full information on these important new products will be sent on request.

Electroline Company

4121 South La Salle Street • Chicago 9, Illinois

However Supported

. . . All Simplex Aerial Cables Provide These Worthwhile Advantages Over Open Wire Lines:

- Little tree trimming required
- Elimination of crossarms
- Smaller clearances needed
- Less congestion
- Better appearance
- Fewer service interruptions when exposed to winds, icing, lightning, and moisture
- Lower reactance; Better regulation
- Higher safety factor for linemen and for people and property below
- Lower maintenance costs

Simplex Aerial Cables are available for power, communication, and control systems of utilities, industries, railroads, police and fire departments.

They can be insulated with the famous moisture-resistant Anhydrex insulation, or with paper, varnished cambric, or polyethylene in order to meet the demands of each type of service. They are protected by either a neoprene jacket, a lead sheath, metallic tapes, treated braids, Plastex or polyethylene jackets, depending on the insulation used and upon service conditions.

The type of cable and method of installation should be decided upon only after a careful study of service requirements. Simplex engineers are always on hand to help you. Feel free to write for their assistance at any time.

SIMPLEX WIRES & CABLES

SIMPLEX WIRE & CABLE CO., 79 SIDNEY ST., CAMBRIDGE 39, MASS.

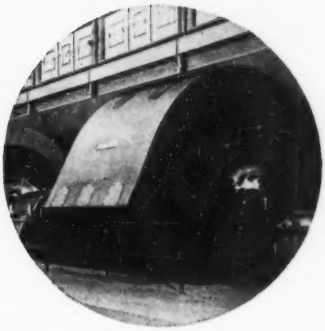
Trade-mark

The mark of quality and experience

Behind this trademark lie 56 years of experience in the manufacture of quality electrical insulation.

Mica Insulator Company was born and has grown with the electrical industry. Its founders were associated with the early development of the Edison generator and motor. From its inception, the company has devoted its efforts to supplying better electrical insulating materials to meet increasingly exacting requirements.

For the further development of fine electrical insulation, there is no substitute for this experience.



meeting the public utilities' needs

In research and product development, we have worked closely with the Public Utilities to develop reliable insulation for power generation, transmission and use. This cooperation has produced many improvements in insulating materials specifically for Public Utility applications.

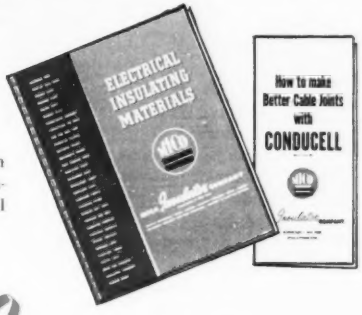
a complete line of insulating materials

Among special products developed for the Utilities are CONDUCELL* and EMPIRE UTILITY BIAS TAPE**. CONDUCELL has set new standards for soundness of underground cablejoints, and UTILITY BIAS TAPE is unsurpassed for retaining high dielectric strength under elongation. MICANITE (built-up Mica), EMPIRE (varnished cloth paper and fiberglas) and LAMICOID (laminated plastic) products round out a complete and diversified line.

technical service

Every electrical insulating problem is a challenge and an opportunity to improve the performance of electrical equipment. We gladly offer our experience and facilities to assist you in solving your insulation problems.

*Reg. U. S. Pat. Off.
**U. S. Pat. No. 2,355,632



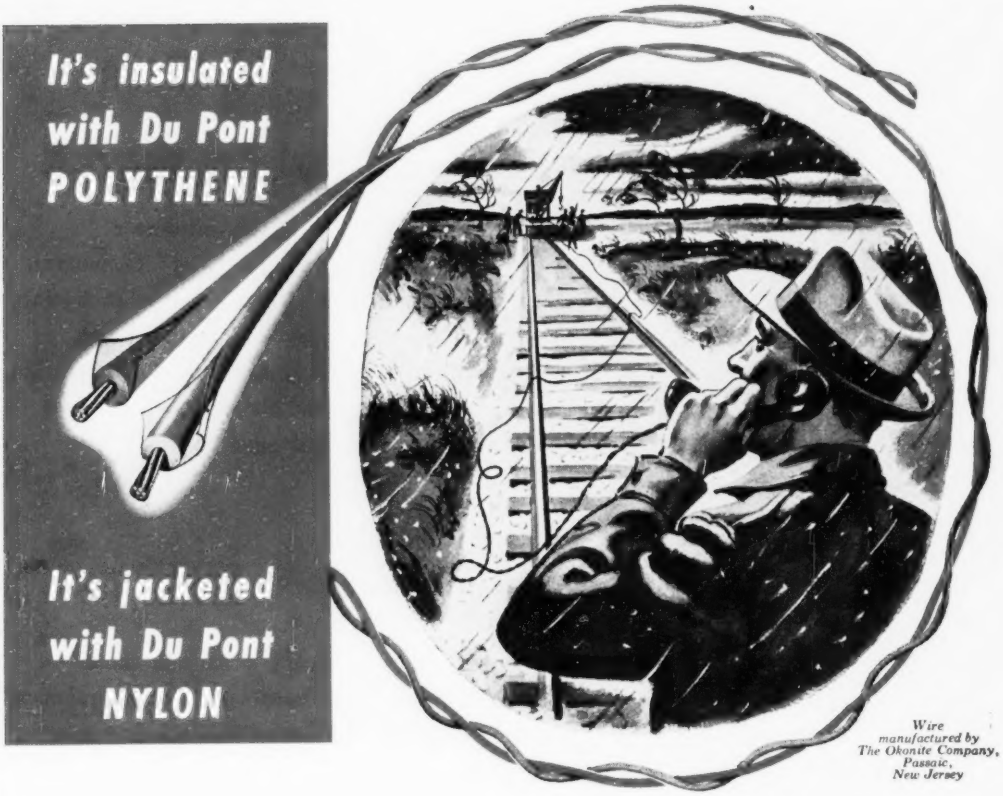
For information that will help you in the selection and application of insulation, send for the catalog, "Electrical Insulating Materials."

Here's a way to make cable joints in underground transmission systems as sound as the original insulation of the cable. It's the CONDUCELL method. Send for your copy of the CONDUCELL Folder A.

MICA *Insulator* COMPANY

Schenectady 1, New York

New emergency field wire has minimum diameter... maximum toughness



Wire manufactured by The Okonite Company, Passaic, New Jersey

HERE'S A NEW WIRE used by railroad companies for severe outdoor service on emergency communication installations. It's light in weight—easy to carry and rig. It's small in diameter—convenient to store. And it's tough enough to withstand constant dragging over rough terrain . . . in all kinds of weather. That's because the wire is insulated with Du Pont polythene and jacketed with Du Pont nylon.

Since Du Pont polythene has such outstanding electrical properties, a thinner coating is needed to do a given job of insulation. It's flexible and resilient . . . resists many deteriorating influences that ruin ordinary insulation. The polythene is extruded directly on the twisted strands of copper wire.

To assure added protection against abrasion from jagged rocks and rubble, the insulation is covered with a thin extruded jacket of Du Pont nylon. For tough, durable nylon withstands strenuous wear. Greases, oils, most chemicals, high and low temperatures won't hurt it.

Perhaps nylon, polythene or another Du Pont plastic can help *you* make a better product. Both nylon and polythene can be readily molded or extruded. Before designing electrical parts or wires, look into their remarkable properties.

Write for free literature: E. I. du Pont de Nemours & Co. (Inc.), Plastics Department, Room 125, Wilmington 98, Del.

DU PONT
REG. U.S. PAT. OFF.
Plastics
BETTER THINGS FOR BETTER LIVING
. . . THROUGH CHEMISTRY

The Last Word in Connectors---

FARGO'S TWO BOLT HEAVY DUTY SERIES

7000 Series

Developed for heavy duty distribution and transmission applications.

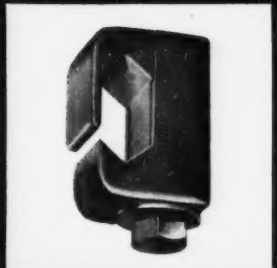
It has---

1. More mass for greater heat dissipation under short circuit conditions.
2. Bronze body for mechanical strength.
3. Two Duronze bolts for added compression force.
4. Wide jaws for larger contact area.
5. Copper spacer for low resistance contact between conductors.
6. Fitted grooves, conductor shaped, for good contact between strands.
7. Greater enclosure of conductor to retard corrosion.
8. All the advantages of FARGO one-piece vise-type construction.

"Built like a vise — grips like a vise"

5000 Series

The popular connectors for routine distribution — primaries, secondaries and services. It has "V" grooves for flexibility of wire sizes, high compression ratio and good electrical and mechanical stability.
"Easy-to-use" one-piece, vise-type construction. Only two bolt head sizes for 8 sizes of FARGO connectors. (No. 8 to 4/0)



FARGO

Distributed by
LINE MATERIAL COMPANY
Milwaukee, Wisconsin

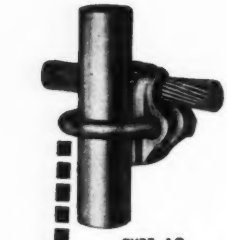
Manufactured by
FARGO MFG. COMPANY, INC.
Poughkeepsie, N. Y.

LM

O.Z. KNOWS CONNECTORS

FROM THE GROUND UP

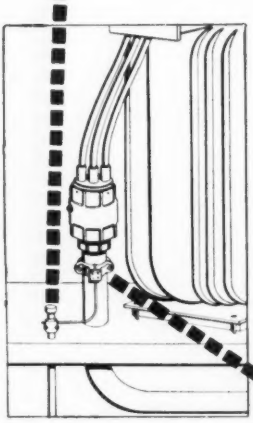
Whether in the depths of a mine or the towers of a skyscraper, wiring jobs done with O. Z. fittings *go in faster... stay in longer.* For typical reasons, check the advantages, below, of just two of the many O. Z. ground connectors. You'll see why engineers say— **"They're OK if they're *O. Z.*"**



TYPE AG

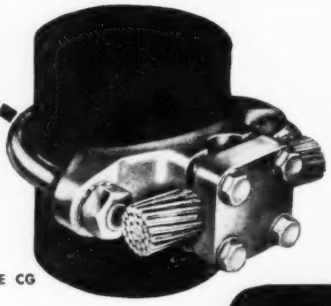
TYPE AG GROUND CONNECTORS

- Top clamp plate is ribbed for strength... eliminates distortion.
- High-conductivity copper alloy... resists corrosion.
- Interlocking pivoted clamp insures maximum circular pressure.
- Single Everdur U-bolt secures cable to ground rod... reduces assembly time.
- Each fitting accommodates a wide range of cable sizes.



TYPE CG GROUND CONNECTORS

- Ground wire connects at right angles or parallel to pipe.
- Universal clamp assures positive contact in either direction.
- High-conductivity copper alloy... resists corrosion.
- Everdur U-bolt can be clamped in place on rod or pipe and ground cable fastened as a secondary operation.
- Each fitting accommodates a wide range of wire sizes.



TYPE CG

More and more electrical wholesalers are stocking O. Z. fittings. See your local distributor today. Write us for catalog detailing sizes, features, and prices of the complete O.Z. line.

3304

CONDUIT FITTINGS • CABLE TERMINATORS
CAST IRON BOXES • SOLDERLESS CONNECTORS
GROUNDING DEVICES • POWER CONNECTORS

O.Z. ELECTRICAL MANUFACTURING COMPANY
262 BOND STREET · BROOKLYN, 2 N. Y.

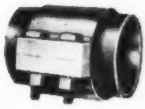
FOR POWER DISTRIBUTION...

O.Z. HAS A COMPLETE LINE OF ELECTRICAL FITTINGS

CONDUIT FITTINGS

CABLE SUPPORTS CONDUIT TYPE

INSULATED BUSHINGS



SPLIT COUPLINGS

EXPANSION FITTINGS

Whether you need grounding connectors or some other electrical fittings, look into the *complete* O. Z. line.

Improved and expanded, it has earned acceptance throughout the electrical industry. Every item is well designed, made of the best material with the most careful workmanship. Every item does its job and does it *right* because O. Z. knows power distribution, knows what you need and gives it to you when and where you need it.

If you don't have an O. Z. Catalog, send for one. Decide what you need, then let O. Z. help make your job easier.

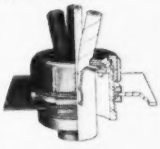
CAST IRON BOXES

WEATHER PROOF TYPE

EXPLOSION PROOF TYPE

CABLE TERMINATORS

TERMINATING POTHEADS



SEALING BUSHINGS

POWER CONNECTORS

T-CONNECTORS, TUBE TO MULTIPLE CABLE TYPE

BUS BAR CLAMPS

SOLDERLESS CONNECTORS

COMBINATION LUGS

COMBINATION TWO-WAY CONNECTORS

COMBINATION TEE AND PARALLEL CONNECTORS

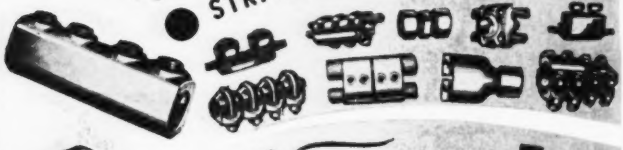
You can find the

EXACT FITTING

you need — in the

SERVICE CONNECTORS

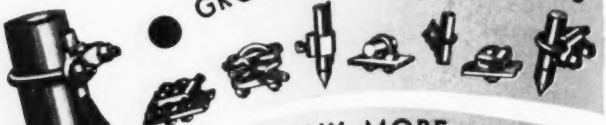
STRAIGHT CONNECTORS



TEES

LUGS

GROUNDING CONNECTORS



and MANY MORE

PENN-UNION Catalog

The conductor fittings shown here can only suggest the wide variety. You'll find practically every good type, in a complete range of sizes.

New connectors are constantly being added - - so when you need a special fitting for an unusual service, tell us about it. Most likely we have exactly what you want.

Better design is a Penn-Union feature that you'll appreciate. For example, note the large gripping surfaces for wrenches, on the service connector shown in the upper left corner. When you use any Penn-Union fitting, you are sure that it is dependable - - mechanically and electrically.

Preferred by Leading Users, who have found that the "Penn-Union" mark on a connector is their best guarantee of unfailing service.

Sold by Leading Wholesalers

PENN-UNION ELECTRIC CORP.
ERIE, PA.

Canada: Dominion Cutout Company, Ltd., 250 Richmond St. West, Toronto

THE *Complete* LINE OF CONDUCTOR FITTINGS

PENN-UNION

"penta-chlorophenol means clean positive protection!"

Shrewd light and power men specify PENTAchlorophenol for poles and cross arms. Here are some of the reasons why:

1. "PENTA" is a preservative of proved effectiveness.
2. "PENTA" is stable and uniform—allows measured and permanent protection.
3. "PENTA" is a nonconductor—creates no special problems.
4. "PENTA" is economical to use—helps reduce maintenance costs.
5. The "PENTA" treatment is a clean treatment . . . Linemen prefer it!

THE DOW CHEMICAL COMPANY • MIDLAND, MICHIGAN

DOW
penta-chlorophenol

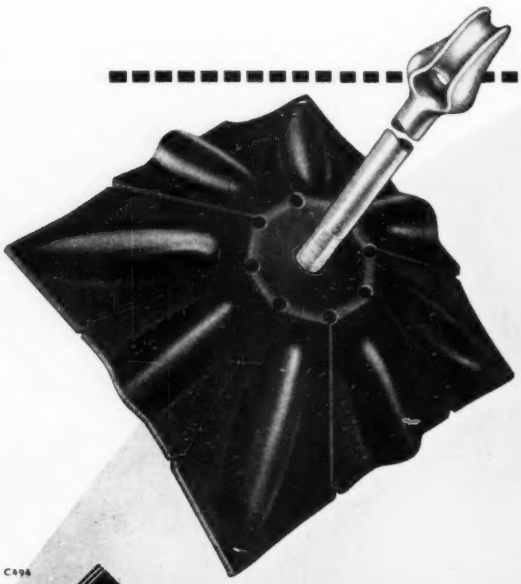
Chance Anchors

GET THE MOST FOR YOUR MONEY—SELECT ANCHORS FROM THE MOST COMPLETE LINE

Whatever your guying requirement may be, there's a Chance Anchor that will do the job most efficiently. The Anchors shown here are made in a wide variety of sizes. Each type is designed for certain soil and guying conditions. One of these Anchors will do a specific job better than any other anchor you can choose.

Standardization has advantages wherever it is practical, but remember that both the soil conditions and type are important factors in determining the type and kind of Anchors to use That's why Chance Anchors are made in so many different types and sizes. That's why it pays to analyze each job and specify the Chance Anchor that meets the requirements.

Only Chance and Chance-licensed Anchor Rods and Guying Fixtures have the improved full-rounded Thimbleye that gives complete guy strand protection at any angle. The full rounded groove fits snugly around the guy strand and prevents kinking, flattening or spreading after installation or during slack pulling operations.



CHANCE 8-WAY EXPANDING ANCHOR

The latest contribution to better anchoring, the Chance 8-Way, gives you more holding power for less money. Better load distribution makes this new anchor stronger than any other expanding anchor. There is no wasted area. The load is distributed evenly over 8 blades which expand to form a cone-shaped square. Repeated pull-out tests demonstrate that the 8-Way develops more holding power and less creep than any other expanding anchor of comparable size under similar conditions, and that it retains its shape under extremely heavy loads.

Simplified construction makes the 8-Way easier to expand and more applicable to varied conditions. This simplicity also saves on manufacturing costs — a saving which is passed on to the user.

More than 13,000,000 Chance Anchors have been put in service—*more than all other makes combined.*

C496

ABC INDUSTRIES

You know it's RIGHT

A. B. CHANCE COMPANY—CENTRALIA, MO.

FOR EVERY GUYING NEED!

NEVER-CREEP ANCHOR
Made of structural steel. Pulls *entirely* against solid, undisturbed earth. For extra heavy loads in clay or loam.

NO-WRENCH SCREW ANCHOR
Sharpened steel blade double-welded to rod. Screws into ground with bar. For light loads in sandy soil, soft clay or loam.

WRENCH-TYPE SCREW ANCHOR
All steel—double arc welded. Anchor hub absorbs installation strain. For light loads in sandy soil, soft clay or loam.

PYRAMID CONE ANCHOR
Acts as inverted wedge. Flaring base and flat faces increase wedging action. Used in rocky areas with rock wedging.

EXPANDING ROCK ANCHOR
No grouting necessary. The greater the pull—the tighter it wedges against solid rock. Set in 2″ drilled hole.

SWAMP SCREW ANCHOR
For swamps, marshes, quicksand, river crossings or seasonally flooded areas. Screws down deeply by adding sections of pipe.

4-WAY STEEL EXPANDING ANCHOR
For years the leading expanding anchor—all steel with reinforced expanding arms. Usually installed in clay or loam.

2-WAY STEEL EXPANDING ANCHOR
Same construction as 4-way—used for lighter loads. Blades expand in opposite directions balancing load.

EXPANDING POLE KEY ANCHOR
Keys poles at the butt to reinforce them against unbalanced loads in soft soil. Ideal for congested Urban areas.

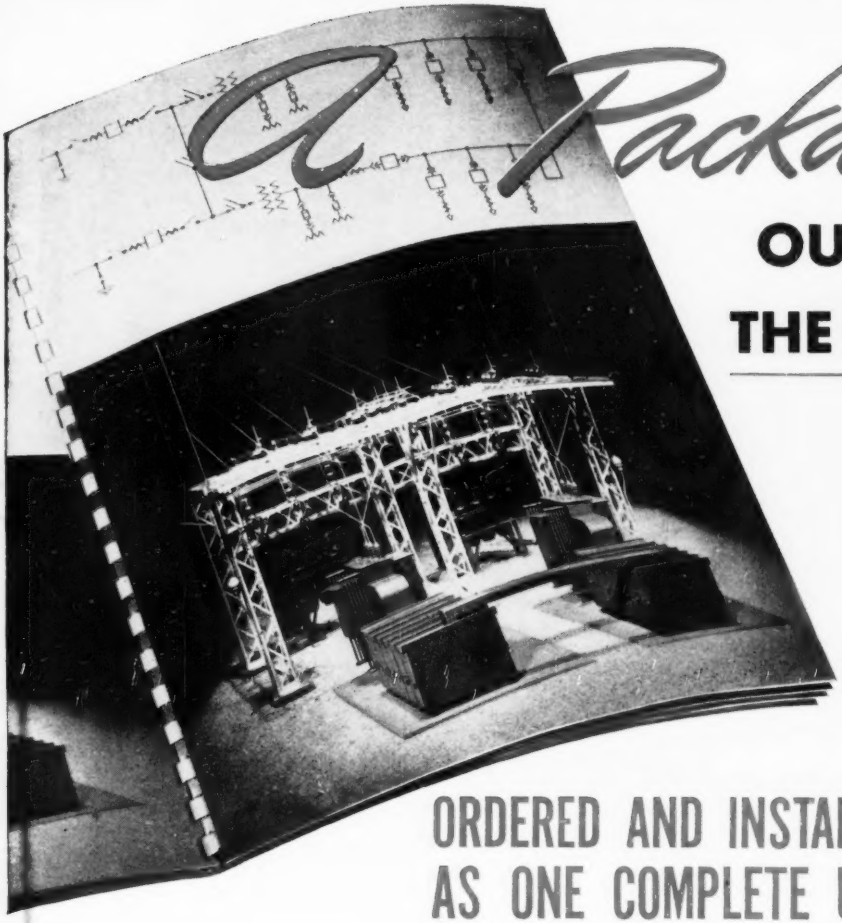
PROTECT YOUR INVESTMENT IN LINE CONSTRUCTION

Get the most efficient anchoring for every condition by making anchor selections from the most complete line. Your Chance catalog will help you in making the right choice. Or write for your copy of "How Much Will an Anchor Hold?" It tells how to determine the type and kind of anchor to use for every guying condition.

when you specify...

A·B·CHANCE CO.
ELECTRICAL TRANSMISSION & DISTRIBUTION EQUIPMENT FOR CONSTRUCTION, MAINTENANCE & OPERATION

SAN FRANCISCO, CALIFORNIA



A Package OUT OF THE BOOK

ORDERED AND INSTALLED AS ONE COMPLETE UNIT

Only one order and one set of specifications were needed for all the equipment of the above substation. Transformers, switchgear, steelwork, lightning arresters, disconnects—everything but the conduit, foundations and enclosing fence—was ordered and installed as a unit.

SAVED TIME—CUT COSTS

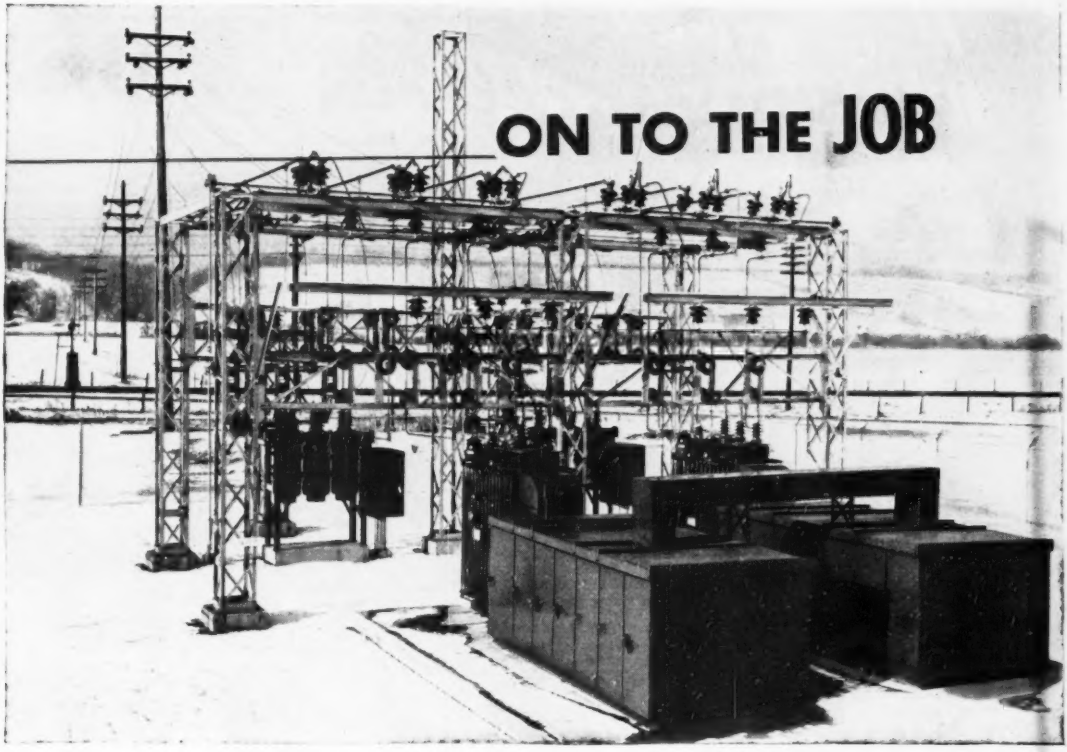
This eliminated months of costly "piecemeal" planning—made it possible to place the order without delay. It made installation quick and easy too—the package substation was shipped in factory-assembled sections as large as shipping facilities permitted.

More and more utilities are finding it easy, economical and highly practical to select—from the hundreds of standard designs—a complete package substation matched to each specific job. They find it frees system engineers of much detail work on components, lets them concentrate more profitably on over-all system operations.

A 'PROVED' PRACTICAL APPROACH

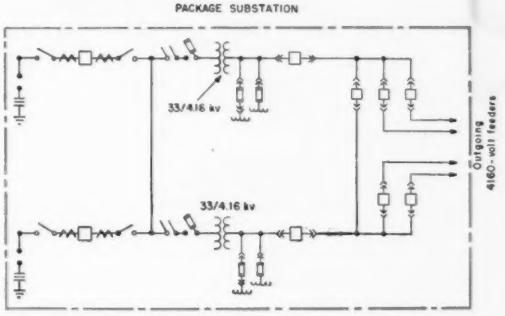
Two years ago G.E. introduced the "Package Substation" as one of the solutions to the difficult economic and manpower problems facing the electric utility industry. The unusual acceptance of the idea is indicated by the fact that over 500 of these complete package substations have been purchased by electric utilities since publication of our package substation bulletin (GEA-4500) two years ago.

Substation . . .



SAVE TIME AND MONEY WITH THE *UNIT APPROACH*
—GET THE COMPLETE SUBSTATION AS A *UNIT*.

Thirty of the basic package substation arrangements are shown in GEA-4500 (left, above). Use it to investigate the *unit approach* to your next substation application. We think you'll be pleasantly surprised. Your G-E sales representative will gladly provide a copy and help you all he can. *Apparatus Dept., General Electric Company, Schenectady 5, N. Y.*



GENERAL ELECTRIC

221-66

CONDULETS*

have grown with the electrical industry

The original CONDULET line in 1905

From 5 items in 1905 to more than 14,000 types and sizes

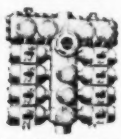
Crouse-Hinds Company, established in 1897, was already well known to the electrical industry when CONDULETS were first introduced in 1905.

The present CONDULET line consists of thousands of types and sizes of cast metal electrical conduit outlet bodies, housings, lighting fixtures, plugs and receptacles. There is a complete line of CONDULETS for use in non-hazardous locations; VAPOR-TIGHT CONDULETS for use where exposed to weather, moisture, steam, or non-combustible dust; DUST-TIGHT CONDULETS for use where combustible dust creates hazardous conditions; and EXPLOSION-PROOF CONDULETS for use in flammable atmospheres.

Complete listings of each type are in the Condulet Catalog.

*CONDULET is a coined word registered in the U.S. Patent Office. It designates a product made only by the Crouse-Hinds Company.

Type DVP Dust-Tight Panelboard, Class II


Type EDP Explosion-Proof Panelboard, Classes I and II

ET Series Explosion-Proof Telephone

Type C Obround Condulet with Switch

Type FS Vaportight Push Button Switch Condulet

Type F Service Entrance Cap

Type VC Vaportight Lighting Fixture Condulet

Type EVA Explosion-Proof Lighting Fixture Condulet

Type FLS Explosion-Proof Motor Circuit Disconnecting Switch

Type GS Condulet

Type ARE Arktite Plug Receptacle

Type YSW Vaportight and Weatherproof Condulet for One or Two Circuit Breakers

Type CES Explosion-Proof Delayed Action Arktite Plug Receptacle Condulet

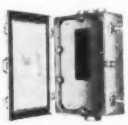
Type EPC Explosion-Proof Circuit Breaker Condulet

Type GRF Junction Condulet with Mounting Lugs

Type GUAC Explosion-Proof Junction Condulet

Type DLA Dust-Tight Lighting Fixture Condulet

Type FS Condulet with Pilot Lamp Receptacle Switch and Plug Receptacle


Type WBP Weatherproof Panelboard with Six Circuit Breakers

Type EFSC Explosion-Proof Push Button Switch

Type ECD Explosion-Proof Breather

Type EVF Explosion-Proof Fluorescent Lighting Fixtures 1, 2, 3, or 4 Lamp

Type FS Three-Gang Condulet with Threaded Cap Receptacle Housing Pilot Light and Tumbler Switch

CROUSE-HINDS COMPANY
Syracuse 1, N. Y.

A Nationwide Distribution Through Electrical Wholesalers

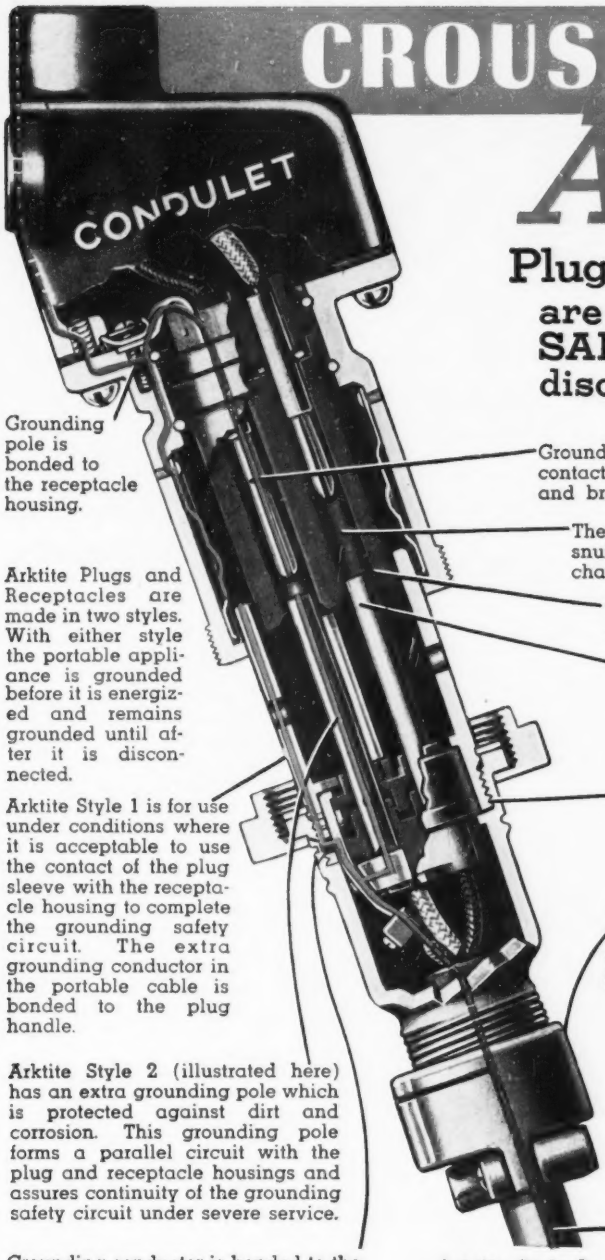
Offices: Birmingham — Boston — Buffalo — Chicago — Cincinnati — Cleveland — Dallas — Denver — Detroit — Houston — Indianapolis — Kansas City — Los Angeles — Milwaukee — Minneapolis — New York — Philadelphia Pittsburgh — Portland, Ore. — San Francisco — Seattle — St. Louis — Washington. *Resident Representatives:* Albany — Atlanta — Baltimore — Charlotte — New Orleans — Richmond, Va. — Salt Lake City
CROUSE-HINDS COMPANY OF CANADA, LTD. *Main Office and Plant:* TORONTO, ONT.

CONDULETS · TRAFFIC SIGNALS · AIRPORT LIGHTING · FLOODLIGHTS

CROUSE-HINDS

Arktite

Plugs and Receptacles are circuit breaking and SAFE without additional disconnect equipment.



Grounding pole is bonded to the receptacle housing.

Arktite Plugs and Receptacles are made in two styles. With either style the portable appliance is grounded before it is energized and remains grounded until after it is disconnected.

Arktite Style 1 is for use under conditions where it is acceptable to use the contact of the plug sleeve with the receptacle housing to complete the grounding safety circuit. The extra grounding conductor in the portable cable is bonded to the plug handle.

Arktite Style 2 (illustrated here) has an extra grounding pole which is protected against dirt and corrosion. This grounding pole forms a parallel circuit with the plug and receptacle housings and assures continuity of the grounding safety circuit under severe service.

Grounding conductor is bonded to the plug handle.

Arktite Style 2. Sectional View

Grounding pole is longer than the others so contact in the grounding circuit is made first and broken last.

The arc formed by pulling the plug is instantly snuffed in the confined insulated arcing chamber.

Each plug contact fits closely the opening of its individual arcing chamber.

The arc is broken while the plug contact is still a considerable distance inside of the arcing chamber. There is no danger of the arc traveling over to the other side of the circuit or to the housing.

Two-piece plug is easy to take apart and reassemble.

Direct-pressure clamp insures postive grip on the conductor cable.

CROUSE-HINDS offers the only complete line of circuit breaking plugs and receptacles—20 Amp. to 400 Amp., 250 volt D.C., 600 volt A.C.

Complete listings are in the Condulet Catalog.

The green line indicates the grounding safety circuit.

A Nationwide Distribution Through Electrical Wholesalers

CROUSE-HINDS COMPANY

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Offices. Birmingham — Boston — Buffalo — Chicago — Cincinnati — Cleveland — Dallas — Denver — Detroit — Houston — Indianapolis — Kansas City — Los Angeles — Milwaukee — Minneapolis — New York — Philadelphia Pittsburgh — Portland, Ore. — San Francisco — Seattle — St. Louis — Washington. *Resident Representatives:* Albany — Atlanta — Baltimore — Charlotte — New Orleans — Richmond, Va. — Salt Lake City

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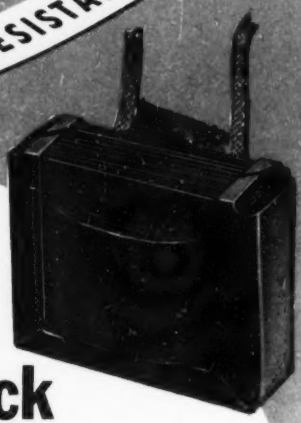
DIP TANK STABILITY

HIGH TEMPERATURE LIFE

MOISTURE RESISTANCE

FLEXIBILITY



IRVINGTON'S #100 clear #500 black INSULATING VARNISH

(Internal Drying)

Here are high dielectric strength varnishes that are "tops" in insulation protection for high heat applications requiring high temperature flexible life. These varnishes remain tough, flexible and stable under the most rugged operating conditions. They penetrate deeply, dry from the inside, bind coil windings into a unit acting mass, preventing movement of wires. They resist damaging heat, moisture, oil, acids, alkalies . . . and will not attack enamel coating on magnet wire.

Use #100 where a clear varnish film is required for instrument coils, field coils, transformers and similar wound structures . . . leads remain flexible and are easily identified where color coded.

Use #500 where an exterior black coating, plus all of the excellent properties of Irvington #100 are needed . . . fine for infra-red baking. This varnish is suited to motor coils, wound stators and field coils.

Both #100 and #500 can lower manufacturing cost, and improve product quality. Try them. Samples, with complete technical data, sent upon request.

"Look to Irvington **for Continued Leadership in Insulation"**

IRVINGTON *Varnish & Insulator Company*

Irvington 11, New Jersey

Authorized distributors in Atlanta; Baltimore; Berkeley; Bluefield, W. Va.; Boston; Charlotte; Chicago; Cleveland; Dallas; Denver; Detroit; Los Angeles; Milwaukee; Minneapolis; New Hartford, N.Y.; New Orleans; Philadelphia; Pittsburgh; Portland, Ore.; St. Louis; Seattle; Hamilton, Ont., Canada.

THIS MAN WORKS *Faster Better Safer*

Because the

Murray CROWS'NEST

affords FIRM, SURE FOOTING
PROPER HEIGHT
WIDE REACH
COMPLETE ROTATION

plus—

The Unmatched *Safety* of Non-Metallic Construction and Semi-Automatic Operation

Steadier . . . stronger . . . safer — that's the Murray demountable Crows'nest, the world's most versatile aerial maintenance ladder. Use it for servicing street lights, inspecting overhead lines, trimming trees, connecting service entrance cables, restoring service when lines go down. Easily operated by only one man, yet strong enough to support ten . . . steady as the truck chassis itself . . . with the inherent safety around high voltage wires that only wood construction achieves!

Murray Crows'nest aerial ladders are available in working heights of 26, 28, 30, 32, 35, 40, 45 and 50 feet. (Ladder at left is the 40 foot size.) They can be mounted on any ¾ ton (or larger) truck weighing 2700 pounds or more. To free the truck for other work, the entire assembly is demounted by removing a single bolt. Write for descriptive bulletin.

Murray

MANUFACTURING CORPORATION

50 Years of Service to the Electrical Industry

1250 ATLANTIC AVENUE • BROOKLYN 16, NEW YORK

Check Murray on your requirements for

Cable Racks — Cable Protectors
Manhole Wall Inserts
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Padlock Seals — Disconnect Plugs
Perforated Strapping — Cable Grips

SERVICE ENTRANCE & METER EQUIPMENT • MAGNETIC CIRCUIT BREAKERS
SWITCHES • CURRENT LIMITING REACTORS • CROWS'NEST AERIAL LADDERS

ORANGEBURG
FIBRE CONDUIT

Safeguarding America's "Nervous" System
UNDERGROUND

Electric light, heat, power, communications . . . these UTILITY COMPANY services depend on the maintained effectiveness of a vast network of "nerves"—underground cables. These cables must have *permanent protection.* ORANGEBURG CONDUIT'S smoother bore and low coefficient of friction gives them this protection from . . . (1) *cable sheath abrasion* . . . (2) *strains* due to *pulling tension* . . . (3) *corrosion* . . . (4) *wear on sheath* from cable movement with changing loads.

For over 50 years, ORANGEBURG CONDUIT has given permanent protection to cables underground . . . helped the Electrical Industry to maintain a reliable and constant service for its customers.

On the evidence of its 50-year record underground, ORANGEBURG CONDUIT is made of materials so tough and strong that they seem to defy time . . . resist corrosive ground waters and chemical wastes *permanently.* The *pre-installation* story is favorable, too . . . easy to handle, transport, install . . . low initial as well as low maintenance costs.

For more complete information write today for ORANGEBURG Catalog No. 49. Keep it for ready reference in your files.

ORANGEBURG STANDARD—For installation with concrete encasement.

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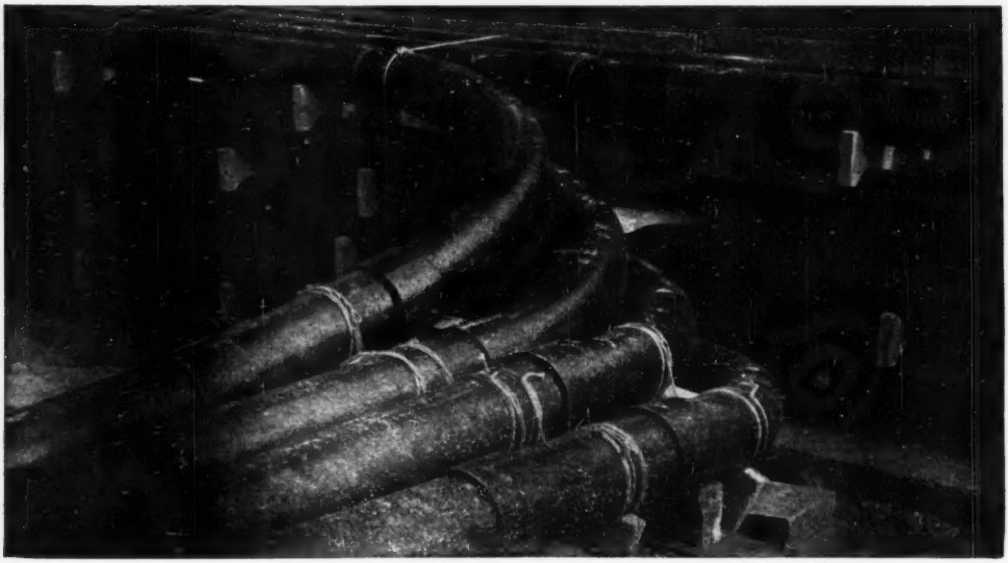


when specifying capacitors

which test

do you go by...

a ten hour lab record?

or a

ten year service

record?

cornell-dubilier capacitors

for power-factor improvement

15 kva., 7,980 v., Single Phase, 60 Cycle, Pole-Type Capacitor

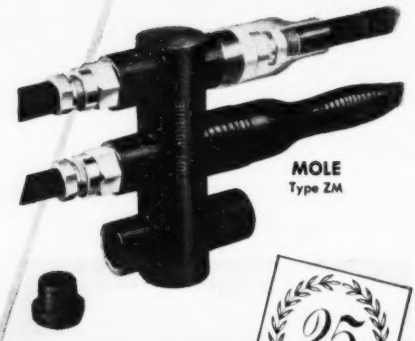
Dependability is a word of exact meaning to engineers. That's why a 10 year record of power plant service with Cornell-Dubilier Capacitors means more to you than a short range lab test for questionable units. C-D's record of achievement speaks for itself: *with over 3,500 C-D power-factor installations in the field, few have needed even minor repairs when operated as long as 10 years.* Here's real dependability — in the full, exact meaning of the word. Contact your C-D field man for experienced power-factor improvement counsel. Cornell-Dubilier Electric Corporation, Dept. D59, South Plainfield, New Jersey. Other plants in New Bedford, Worcester, Brookline, Massachusetts; and Providence, Rhode Island.

CORNELL-DUBILIER · WORLD'S [illegible] MANUFACTURER OF CAPACITORS

Follow the leaders.
Demand dependable C-D Capacitors for your system.

UNDERGROUND

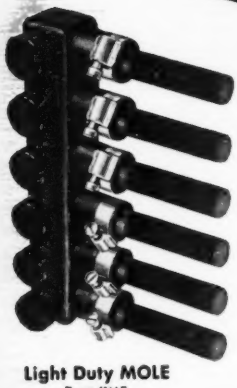
Burndy underground connectors have been time-tested for over a decade in actual service. Preferred because of their rapid installation, flexibility, and low cost. All pre-insulated to eliminate taping wherever possible. Ask for the Mole Line Catalog, or engineering assistance. BURNDY Engineering Company, New York 54, N. Y. WESTERN BRANCH: Vernon 11, California. CANADA: Canadian Line Materials, Ltd., Toronto 13.



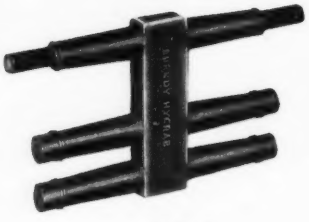
MOLE
Type ZM

25 YEARS OF SERVICE

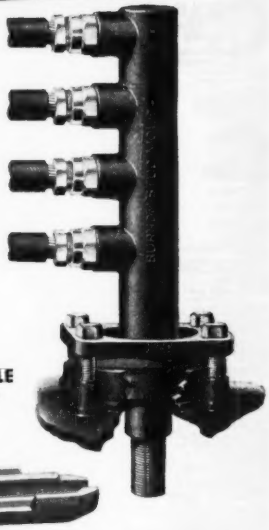
Connect with
BURNDY



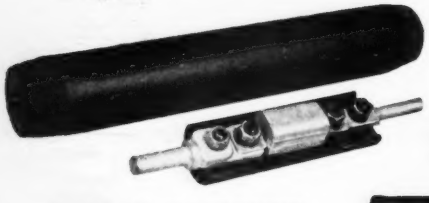
Light Duty MOLE
Type KME



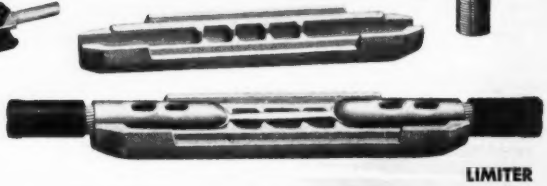
HYCRAB
Type YM



STUD MOLE
Type ZMLD



Replaceable Link MOLIMITER
Type LYM



LIMITER
Type YFS

NOW order G-E Time-Delay Renewable Fuses

in all commonly used sizes

Time-Delay that you can Really Depend on

Measured time-delay action matches General Electric knife-blade-type fuses to today's circuit requirements. New link design uses heavy plates to absorb the heat of momentary overloads—sensitive connecting links for fast action when loads exceed normal peak. New plates have no sharp corners to re-establish contact after fuse is blown.

New General Electric ferrule-type fuses have the extra protection of measured time delay, too. Both types of fuses also have the advantage of new three-piece construction for quick, easy replacement. No small loose parts to worry about. Nothing to juggle while you're changing links. You'll marvel at maintenance speed like this.

Now, it's easier than ever to make the changeover to the new General Electric renewable fuses. A new, wider range of sizes makes these fuses applicable for all commonly-used circuits. So, why not get the habit of specifying General Electric for fuses you know you can depend on?

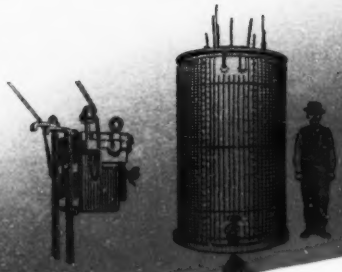
Behind this great new line of fuses are all the reliability and patient research that go with any General Electric product you buy. Careful attention to the maintenance man's needs brought about the simplified three-piece construction of these new fuses. Research into the average requirements of today's circuits produced the measured time-delay of the new fuse links. You know there's dependability in fuses that bear the General Electric name.

So, get the satisfaction of using the new General Electric fuses right away. Order from your distributor today.

For information on the new General Electric fuses, write to Section D33-527, Construction Materials Department, General Electric Company, Bridgeport 2, Connecticut.

You Can Put Your Confidence in—

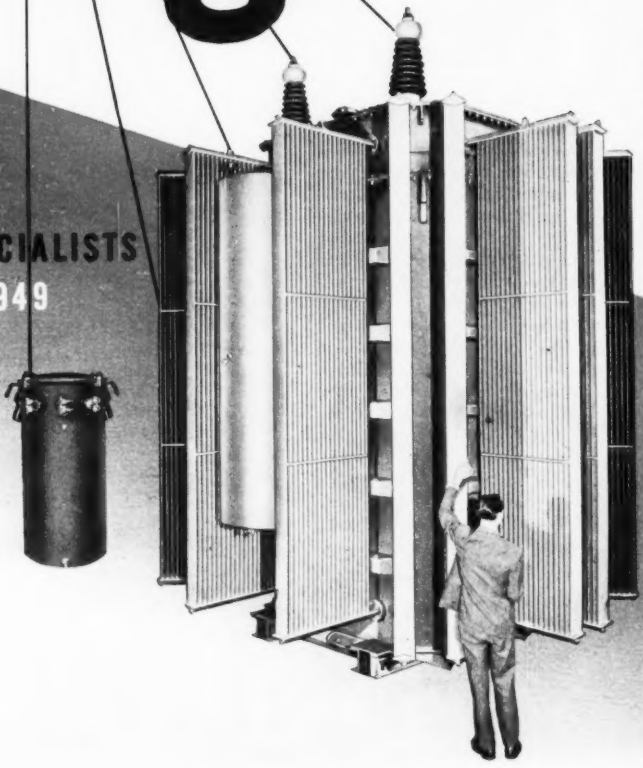
GENERAL ELECTRIC



TRANSFORMER SPECIALISTS
1891

wagner

TRANSFORMER SPECIALISTS
1949



As a pioneer and leader in the development and growth of the electrical industry, Wagner has, through the years, contributed vitally to the American way of life. Part of this contribution has been the designing and manufacturing of transformers for every service.

Wagner Transformers have developed and kept pace with growing power and distribution needs for over half a century. They have won universal acceptance because of their complete dependability.

Twenty-nine branches, in principal cities, will help you with your transformer problems.

Wagner Electric Corporation
6456 Plymouth Ave., St. Louis 14, Mo., U. S. A.

Bulletins TU-180 and TU-181 give complete information on Wagner Transformers. Write for your copies.

ELECTRIC MOTORS • TRANSFORMERS • INDUSTRIAL BRAKES • INDUSTRIAL BRAKE PRODUCTS

T49-13

Accents on Accuracy
in producing WIRE FITTINGS

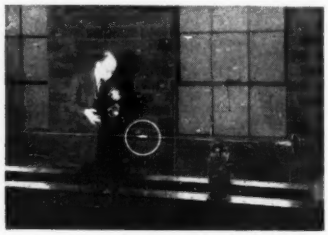
For years wire fittings were designed by men who were primarily electrical engineers although the functions of the fittings were — and still are — almost wholly mechanical.

Branching out from the telephone industry where products and operations involve greater delicacy and even "fussiness", the Reliable Electric Company entered the power industry with a wealth of experience in accurate manufacturing processes.

PIONEERS IN MANY IMPROVEMENTS

Reliable pioneered in the application of good mechanical and metallurgical engineering principles to wire fittings, the elimination of alloys subject to dezincification, the better separation of galvanically dissimilar materials, the improvement of thread surfaces and thread engagement to provide greater efficiency of joints, the addition of fillets or radii in place of square corners which concentrated strains.

Other Reliable originations are the service connector, for joining wires end to end; the concentric cable clamp, for supporting service cables; the flip-on tap clamp, for high pressure connections over armor rods; the pressed ground rod clamp, for high pressure ground connections; and the forged hot line clamp.



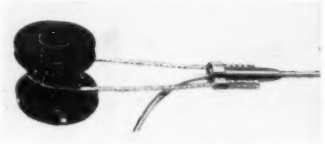
Intricate testing equipment enables Reliable to check product performance equal to years of actual use in a matter of hours.

SCIENCE INSTEAD OF GUESSWORK

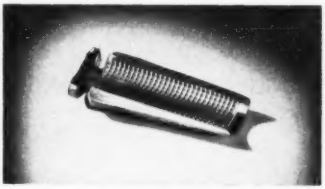
Reliable holds a unique position among fitting manufacturers in having excellent facilities for the study of fatigue stresses in wire vibrations and is able to design and build with mechanical soundness where others have to depend upon field experience.

LIGHTER WEIGHT, LONGER LIFE

Bulky galvanized steel clamps for supporting service cables and for deadending conductors to strain and spool insulators have been made obsolete by Reliable's light, non-ferrous fittings which will last as long as the wire itself under any atmospheric conditions. Reliable's deadend for use with disc insulators is being similarly modified to a light, long-lasting design using stainless steel.



A Reliable deadend is made of light but strong non-ferrous materials.



The heart of the Reliable Straightline Splice is the gripping jaw with it's hard, sharp, tiny points that grip but do not injure the wire.

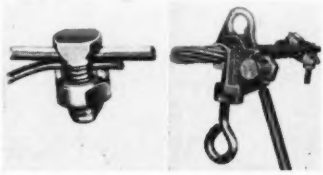
A CONSISTENT PATTERN

Reliable recognizes the fact that in comparison to many improvements made in the power industry, its contribution has to do with only a small part of the progress of the whole, but these contributions follow a consistent pattern of design and manufacture of fittings with the accents on accuracy and efficient use of high strength non-corrosive materials to provide better, longer service in the small but still important items.

NEW STANDARDS ESTABLISHED

Further examples of Reliable's contributions in producing line wire fittings that have established new high standards of mechanical excellence in this field include hard forged splice jaws with hundreds of sharp teeth which bite and hold securely without gashing the wire. An example of Reliable's care in providing for perfect performance is the packing of straightline splices with neutral grease to assure perfect performance and, to avoid any possible chance of dirt particles interfering with this performance, each splice is enclosed in a sealed, dirtproof, airtight cellophane envelope. Little things, perhaps, but indicative of Reliable's care to provide the best.

Straightline splices are protected against dirt infiltration by cellophane packages.



Accuracy in manufacture has enabled Reliable to produce Solderless Connectors and Hot Line Clamps of greatly increased efficiency.

OTHER CONTRIBUTIONS

Hard forged connector bolts with accurately engineered thread contours to provide maximum pressure efficiency, and forged hot line clamps which have eliminated the wasteful weight of porous castings are two more examples of Reliable's efforts to contribute to the progress of the electrical industry as a whole.

POWER-LINE CONNECTORS AND CONSTRUCTION SPECIALTIES

Reliable ELECTRIC COMPANY

3145 CARROLL AVENUE, CHICAGO 12, ILLINOIS

OVER 40 YEARS OF SERVICE TO THE UTILITIES

Utilities are welcoming this modern STREET LIGHTING CABLE ....

The welcome mat is really out at the front door of the utility plants for Ankoseal Street Lighting Cable. For it's modern, all-plastic cable which is destined ultimately to replace other types of cable that were considered satisfactory previously.

One big reason for this changeover is the exceptional inertness of Ankoseal cable *all the way through* to earth acids, duct water, oils and other contaminations which eventually cause cable replacement.

A second advantage is the much lighter weight of Ankoseal Street Lighting Cable. This results in savings of effort at every point of handling from initial delivery to final installation.

A third advantage is its complete resistance to corona cutting or cracking.

With this combination of advantages, light weight and longer service life, there is great potential economy that deserves the investigation of every cost-conscious utility executive.

Ankoseal Street Lighting Cable is available for every street lighting use. It can be supplied shielded or unshielded according to the customer's specifications.

We'll welcome an opportunity to interpret for you the benefits of Ankoseal Street Lighting Cable in your operation. Just write us briefly of your needs.

THE ANSONIA ELECTRICAL COMPANY

SUBSIDIARY OF NOMA ELECTRIC CORPORATION

ANSONIA, CONNECTICUT

YOU CAN BE **SURE**.. IF IT'S

Westinghouse

PROOF

FROM

NORTH CAROLINA

"so far as I am concerned, the 'CSP' is the only transformer"

What backs up this statement by the manager of a southern co-operative, about the "CSP"* Completely Self-Protecting transformer?

In August, 1947, the most severe wind and lightning storm in his long experience lashed the area served by his company. Five breaks in the line were reported, plus two breaks in the neutral. Service trucks were rushed out—and, naturally, they carried replacement transformers.

But not one "CSP" transformer had failed!

This striking proof of the lightning protection built into "CSP" transformers is one reason why 1,050 transformers in the 520 miles of line in this system are "CSP" units. And why only 50 are conventional type.

One thing is sure: the built-in lightning protection of "CSP" transformers lowers maintenance costs. Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pa.

J-70525

**Trademark—Reg. U. S. Pat. Off.*

HERE'S PROOF FROM U. S. A.—Thirty case histories of Completely Self-Protecting transformers, with names, dates, places, facts and figures. Get your copy of B-4248.

Call the Westinghouse Salesman

Westinghouse "CSP" TRANSFORMERS

SINGLE PHASE **THREE PHASE** **BANKED SECONDARY**

For surest cable protection, specify—

BERMICO®

FIBRE CONDUIT

Scientifically Designed and Constructed to Provide Better Cable Protection, BERMICO *is always on the job!*

1 **LIGHT.** Easily handled on the job; one man can carry several 8-foot lengths at once—lay more per working hour.

2 **TIGHT.** All joints are precision milled for light, speedy, installations.

3 **STRONG.** Bermico Conduit is engineered to take the shocks and stresses of transport . . . the heavy loads imposed during installation.

4 **NO SPLIT COUPLINGS.** With Bermico's specially designed couplings, you end the expense—the loss of time required to replace broken couplings.

5 **WATER PROOF.** Bermico's water absorption factor is extremely low—its insulation factor extremely high, even under toughest conditions.

6 **ACID RESISTANT.** Resistant to soil acids and alkalies, Bermico Conduit is, itself, chemically inert.

7 **SMOOTH INSIDE BORE.** Quick and easy cable "pull throughs"—without danger of abrasions—when you're using Bermico *inspected* conduit!

8 **UNIFORM.** Four rigid factory inspections guarantee Bermico's uniformity of dimensions, specifications and quality.

Production facilities and schedules are geared to assure prompt shipments.

distributed by

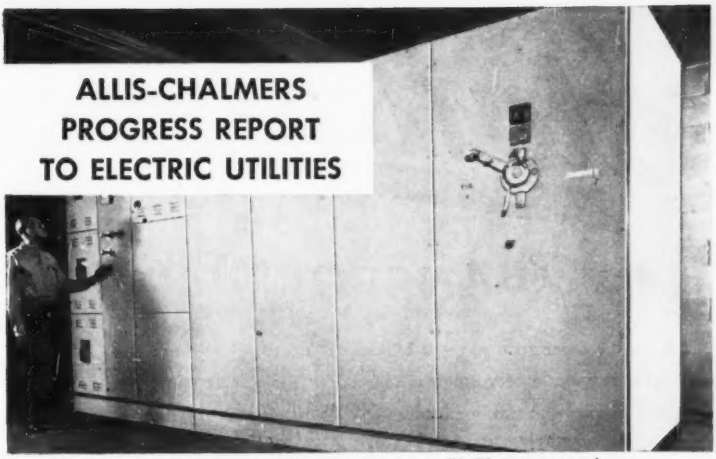
WESTINGHOUSE ELECTRIC SUPPLY COMPANY

Offices in all leading cities

BERMICO FIBRE CONDUIT—A PRODUCT OF BROWN COMPANY

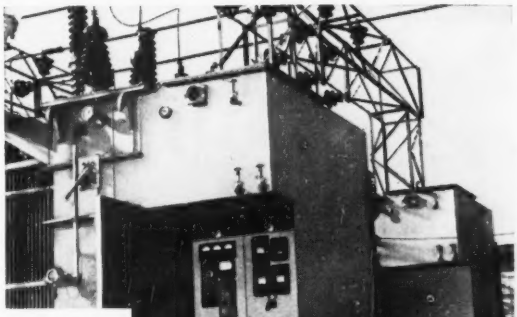
Mills—Berlin, N. H.

ALLIS-CHALMERS PROGRESS REPORT TO ELECTRIC UTILITIES

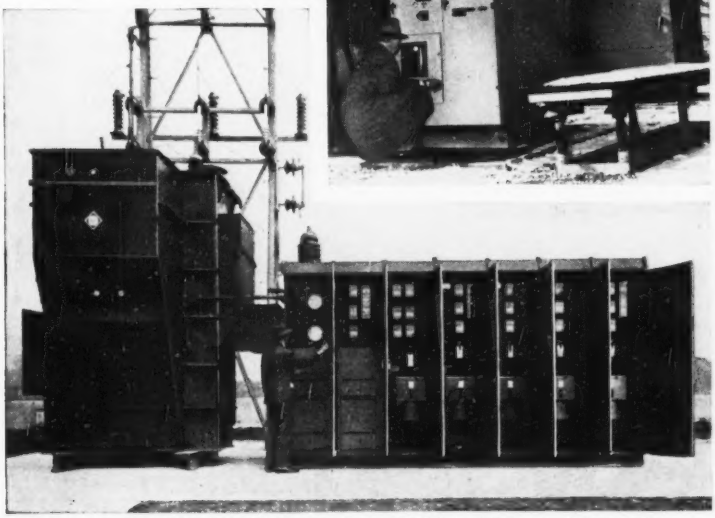


750 KVA LOAD CENTER UNIT-SUB—4160-490 v, incorporates "A-C" dry-type transformer

TWO "SCS" 2000 KVA, 44,000-4160, 3 phase, 60 cycle unit-subs. Single-Circuit



Oil-Sealed is an Allis-Chalmers Trademark



3000 KVA OUTDOOR UNIT-SUB—Includes transformer, ±10% Load Ratio, 7 switchgear units

A-C First with ±10% Load Ratio Control Standard

STANDARDIZATION on Load Ratio Control of one range only (±10%) means that now 32-⅝% steps give standard Unit-Substations the same accuracy and range of regulation as Allis-Chalmers 3-phase feeder voltage regulators . . . better regulation at lower cost!

Along with standard voltage ratings, Allis-Chalmers' standardization program has reduced the number of necessary designs, "board" work and manufacturing costs, resulting in lower prices to Utilities.

R. O. Bell, Mgr., Unit-Substations

Many *detail* improvements in unit substations have also been pioneered by A-C. They include, metal-clad switchgear; controlled gasket compression on transformers; the protective Oil-Sealed inert gas system which operates at pressures usually less than 1 lb; "quick-break" contact separation; drawout auxiliary transformers; no-corona taped bus joints; and the flexible drop collar throat connection.

Together, these improvements are good points to check in purchasing unit-substations. They make the difference between average or above-average performance.

Allis-Chalmers MCS (Multi-Circuit) unit substations consist of two or more vertical lift metal-clad switchgear units throat-connected to one or two transformers.

Allis-Chalmers SCS (Single-Circuit) unit substations consist of a transformer, secondary breaker and control, Oil-Sealed inert gas system, and 32-⅝% step regulator mechanism—all combined within a single housing.

Allis-Chalmers LCS (Load Center) unit substations provide 600 v or lower power sources for auxiliary motor and lighting loads, are installed indoors or out, and on roofs or balconies.

Your nearby A-C Sales office will be glad to provide more details . . . give you full information on the savings that Allis-Chalmers Unit Substations can bring you. ALLIS-CHALMERS, 932A S. 70TH ST., MILWAUKEE, WIS.

A2721

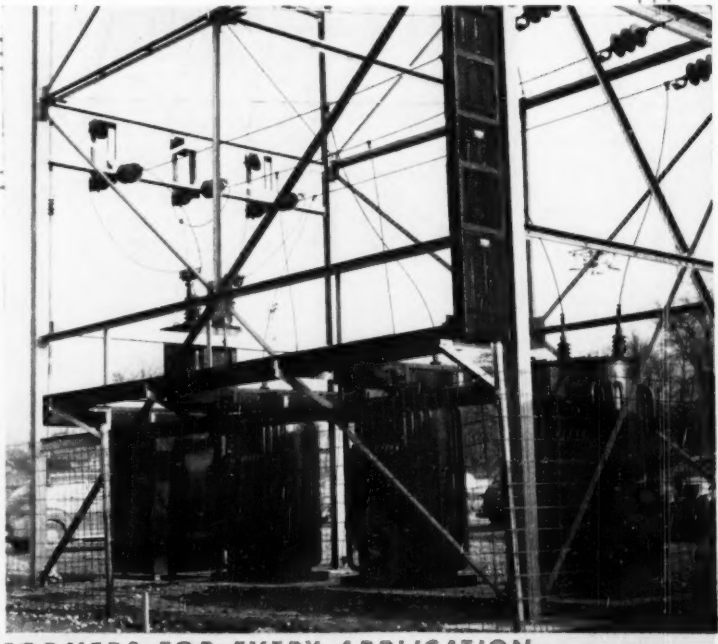
ALLIS-CHALMERS *Pioneers in Power and Electrical Equipment—Builders of the World's Widest Range of Major Industrial Equipment!*

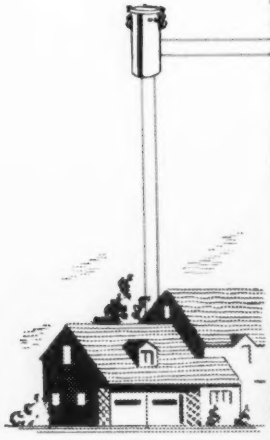
Standard

TRADE MARK ®

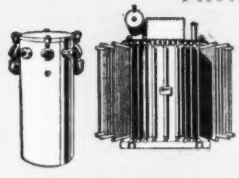
TRANSFORMERS ALL

Have the assurance of peak efficiency "all the way down the line" at every stage of voltage change from the power station to the point of use with the consistency of STANDARD'S transformer performance. STANDARD has provided the electrical industry with dependable transformers for more than 25 years. When you specify STANDARD TRANSFORMERS—you specify the best.

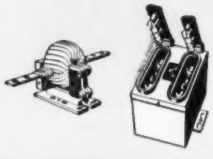




TRANSFORMERS FOR EVERY APPLICATION

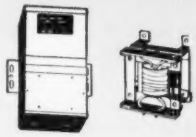


Liquid filled (sizes up to 10,000 KVA and 72 KV inc.)



Instrument transformers (for use on circuits up to 72,000 volts, inc.)

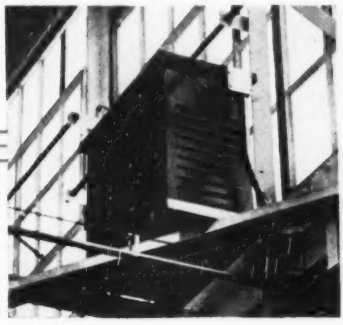
Dry type (up to 1000 KVA and max. voltage ratings of 4800)



Control transformers (compound filled or open type)

THE WAY DOWN THE LINE...

OIL, ASKAREL AIR COOLED



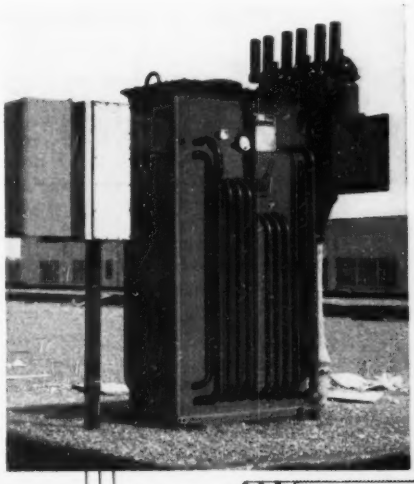
Accepted by people who know from experience

The Standard Transformer Company has the sound foundation of more than a quarter century of specialization in designing and building transformers to meet precise requirements of industries. STANDARD'S research in conjunction with the thinking of utility and industrial electrical engineers combine to produce the best possible transformers. STANDARD TRANSFORMERS incorporate every feature to provide the present day ultimate in flexibility and durability, with greatest safety.

LOAD CENTER DISTRIBUTION

Indoor Since recognition of load center economies and operational advantages is established, engineers' selection of a transformer is influenced by performance records. STANDARD'S dry-type transformers have proved practical because they lend themselves to a great variety of conditions. Built with a minimum of weight and size (consistent with power requirements and capacity margin) this STANDARD DRY-TYPE TRANSFORMER was easily and quickly installed in an out-of-the-way indoor location.

Outdoor Where space and location factors require the advantageous use of non-inflammable liquid cooled types, STANDARD'S Askarel cooled transformers are depended upon for trouble-free service. Here's a load center unit located on a roof. You can specify STANDARD with assurance that, from an engineering point of view, there is no better transformer available, and, from a manufacturing standpoint, expert craftsmanship and best grade materials are combined for quality production. Write, today, for data on any "all the way down the line" STANDARD TRANSFORMERS.



THE STANDARD TRANSFORMER COMPANY

WARREN, OHIO · OFFICES IN PRINCIPAL CITIES

Add years of *Extra Life* to your poles

USS TRADE MARK CREOSOTE OIL UNITED STATES STEEL

with proven

U·S·S Creosote Oil

● Service records show that creosoted poles will give *years* more service than untreated poles . . . how many years depends on conditions under which the poles are used. So, it's good business — the best kind of long-range planning — to insist upon this preservation method for all your poles.

And, when you do, the next most logical step is to specify *U·S·S Creosote Oil.* Here is a wood preservative that has proved itself . . . that has piled up an unbeatable record of dependability among utilities and other users and treaters covering more than two decades.

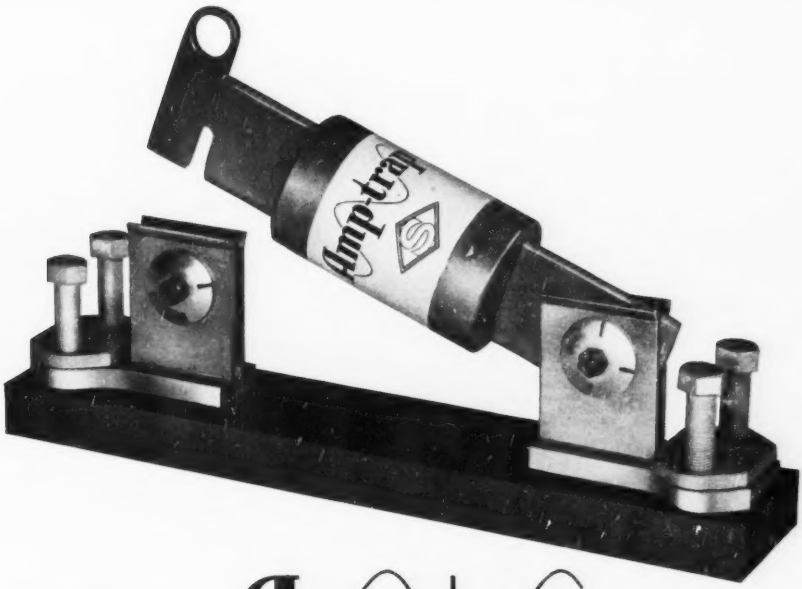
Today, as in the past, you can depend upon the proven ability of U·S·S Creosote Oil to increase the life span of your poles. For it's the product of our own *controlled* processes—all the way from the mining of the coal to the actual production of the creosote oil. It comes from the world's largest distillation plant, where facilities permit a *continuous* method of operation. This means uniformity of product. The good results achieved in the preservation of your poles are duplicated exactly—time after time. There's no variation in the high toxicity of U·S·S Creosote Oil; no change in the effectiveness and adequacy of its penetration.

And remember, whether you need a tank-car load or a full barge, we can offer prompt delivery. Meanwhile, if you have any questions concerning Creosote Oil and what it can do for you, feel free to consult us. There's no obligation.

COAL CHEMICAL SALES DIVISION
United States Steel Corporation Subsidiaries
71 Broadway, New York 6, N. Y.

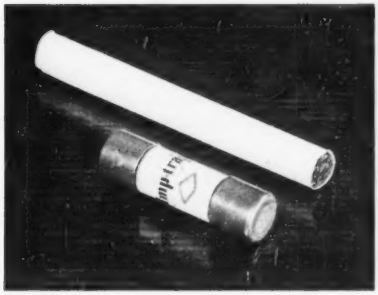
USS **CREOSOTE OIL**

UNITED STATES STEEL



NEW! Amp-trap NEW!

A STARTLING NEW PROTECTIVE DEVICE



A 20-ampere 600-volt Amp-trap (half the size of a cigarette) can tap a feeder directly off a bus capable of delivering a 100,000 ampere short circuit.

Shown above is a 1000-ampere 600-volt Amp-trap in special mounting clips and base, arranged as a disconnecting device. Proven interrupting capacity: 100,000 amperes at 600 volts, alternating or direct current.

which slays the giant of short-circuit interruption, and opens a new era of protection on low-voltage circuits. On both AC and DC circuits, Amp-trap brings relief from damage by short circuit currents to metal-clad switchgear, station auxiliary circuits, bus-duct distribution systems, and industrial control equipment. A product of Shawmut research, it is a current-limiting device without moving parts, and is lightning fast on short circuits. It has the remarkable characteristic that the more severe the short circuit, the greater its magnitude, and the faster it develops, the sooner Amp-trap will cut it off, without noise, flame, or excessive over-voltage. Amp-trap limits the build-up of fault current to a value lower than that obtainable by any other protective device. It has an interrupting ability of 100,000 amperes and higher, on any AC or DC circuit up to 600 volts; and is supplied in all the usual ampere sizes from 1/4 ampere to 4000 amperes. Its interrupting ability is independent of its current-carrying ability; and it possesses many further advantages that give it a new and unique place in the field of circuit protection. Ask today for full information.

THE CHASE-SHAWMUT COMPANY
NEWBURYPORT, MASSACHUSETTS

Boston, New York, Syracuse, Philadelphia, Pittsburgh, Baltimore, Atlanta, New Orleans, Dallas, Detroit, Columbus, Indianapolis, Chicago, Little Rock, Kansas City, St. Louis, Minneapolis, Denver, Los Angeles, San Francisco, Seattle

Reduce Conductor Failure

● Save maintenance, reduce failures by protecting your lines with a simple system of PLP Armor Rods.

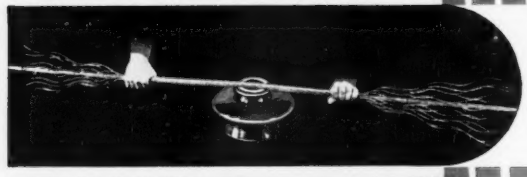
Your first economy comes with installation. Linemen save time . . . do a better job, because they don't *form* Preformed Armor as they apply it. Factory forming assures an accurate specified pitch that guarantees uniform, tight gripping of the conductor. No tools are needed to apply it, no clamps to hold it. On cold lines, PLP Armor Rods are installed entirely by hand. Easy-to-use tools are available for installation on energized conductors. Even inexperienced crews cannot improperly install Preformed Armor.

WATCH THIS EASY INSTALLATION

The lineman takes from half to all rods needed for a complete installation and lays them across and around the conductor. The lay of the rods is in the same direction as the lay of the conductor.

He wraps these rods around the conductor several times. He uses a wiping action of the hands and a motion like wringing water from a cloth.

If necessary, he repeats the first two steps with the remaining rods.



He grasps the entire set of rods and continues the wiping action along the conductor.

Here he has finished one side and is just completing the other.

*Although PLP Armor Rods are available in practically all regularly used metals (galvanized steel, aluminum, copper and bronze), galvanized steel rods offer an opportunity to save more critical metals.

PREFORMED ARMOR RODS ARE FOR USE UNDER PATENT NO. 2,275,019—OTHER PATENTS PENDING.

PLP COMPANY

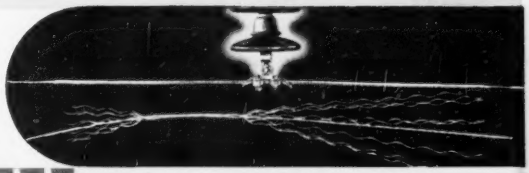
with PREFORMED ARMOR RODS*

Under taps, clamps and ties, PLP Armor Rods protect the conductor from arcs and flashovers. They curb abrasion and chafing . . . dampen vibration. They prevent slippage from unbalanced line tension at suspension points. They eliminate concentrated pressures.

Like to know more about PLP Armor Rods? Any salesman of Line Material Company, Locke Incorporated or American Steel and Wire Company will gladly give you complete information and prices. Or write Preformed Line Products Company, 1051 Power Avenue, Cleveland 14, Ohio.

SEE WHERE TO USE THEM

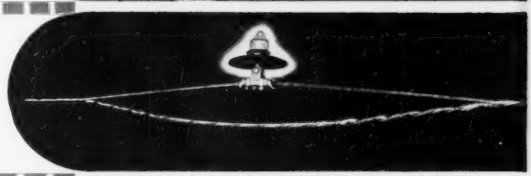
AT INSULATION SUPPORTS . . . PLP Armor Rods curb chafing, abrasion and stresses from vibration. They prevent slipping due to unbalanced line tension . . . guard against possible wear and burning from ties and clamps.



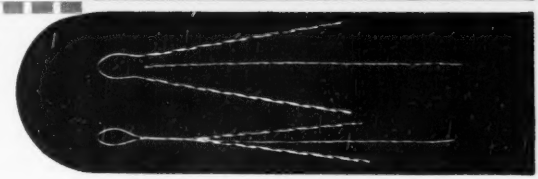
FOR CONDUCTOR REPAIR . . . jumpers for splices and so on, PLP Armor Rods cost less and are faster to install. Where one or more strands of a multi-strand line are severed, PLP Armor restores the original mechanical and electrical characteristics.

FOR MECHANICAL SPLICES . . . Special PLP Armor Rods are available with shorter pitch and closer dimensional tolerances. No tools are needed to make smooth splices. Laboratory tests prove these splices at least 95% as strong as the original strand.

FOR VIBRATION DAMPING . . . At insulator supports, nothing equals PLP Armor Rods. Dampers are quickly built up in the field and easily installed by hand.



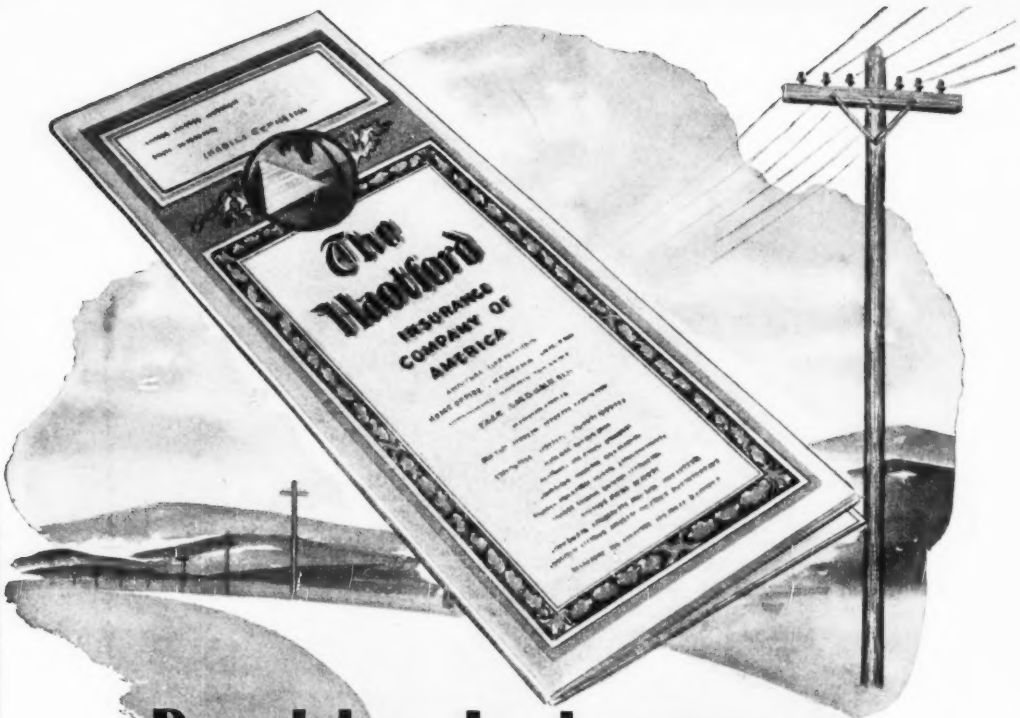
FOR DEAD ENDS . . . The same tight gripping action which PLP Armor Rods develop in splices makes them perfect for deadending. They are installed without clamps or tools.



TO EXAMINE PLP ARMOR RODS AND SEE HOW TIGHTLY THEY GRIP THE CONDUCTOR, ASK US FOR A SAMPLE SET. PROVE IT TO YOURSELF.

PREFORMED LINE PRODUCTS COMPANY

1051 POWER AVENUE **CLEVELAND 14, OHIO**



Double Indemnity

When you specify Penta Preservative for your poles, crossarms or other timber, you are making doubly sure of lasting satisfaction.

It's Certain Pentachlorophenol, the active ingredient of Penta Preservative, has demonstrated its effectiveness both in actual service and in test plots over a long period of time. The Penta you buy today is exactly the same substance as that which established the service records now being reported.

It's Clean Practically odorless and colorless, Penta is the ideal preservative material for wood which is to be handled or worked with. Workmen do not object to climbing Penta treated poles. The treated wood does not cause skin irritation.

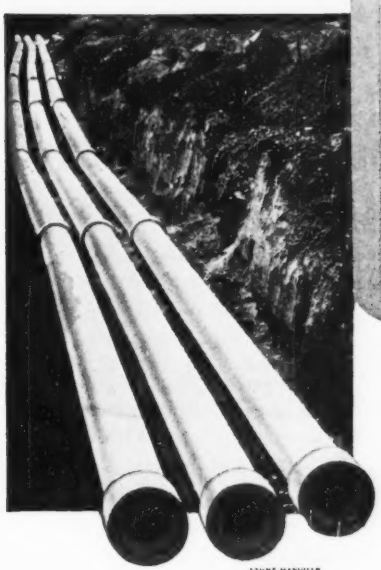
Get double value for your money by insisting on Penta Preservative. Treatment techniques and equipment are the same as for other materials, so any supplier can use Penta without additional cost. In some cases, Penta actually costs less even though it gives far more.

PENTA PRESERVATIVE

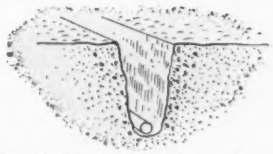
CLEAN • IT'S CERTAIN • IT'S CLEAN • IT'S CER **CHAPMAN** IT'S CLEAN • IT'S CERTAIN • IT'S CLEAN • IT'S

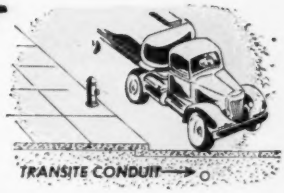
CHAPMAN CHEMICAL COMPANY ★ **757 Dermon Building, Memphis 3, Tennessee**

Do you know these facts about TRANSITE DUCTS?



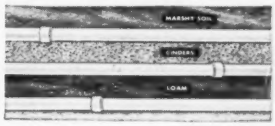
TRANSITE CONDUIT

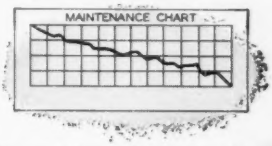




This durable duct is for use underground, or on exposed locations without a protective casing . . .

Under sustained earth loads and traffic pressure, it maintains its strength and true form . . .

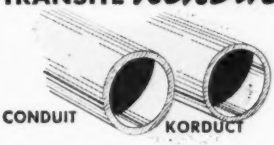


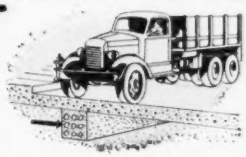


Transite Conduit effectively resists weather, smoke and fumes . . . is virtually unaffected by corrosive soils . . .

Its cost is low and, in service, it is much more economical than other materials of comparable strength and durability.

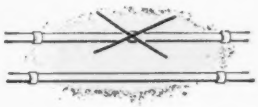
TRANSITE KORDUCT

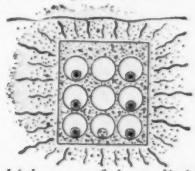




Thinner walled, lower priced than Transite Conduit, Transite Korduct is for use where an encasement is specified . . .

Because Korduct is incombustible, less concrete is required between ducts to provide the necessary degree of fire protection.





Its long lengths (10 feet) mean fewer joints, reducing the number of spacers required . . .

Its high rate of heat dissipation lowers cable operating temperatures . . . increases system capacity . . .

. . . *In addition,* both Transite Conduit and Transite Korduct have these characteristics:

1. INCOMBUSTIBLE—made of asbestos and cement, they cannot burn . . . will not contribute to the formation of dangerous smoke, fumes or gases.

2. IMMUNE TO ELECTROLYSIS—Transite Ducts are nonmetallic and inorganic . . . unaffected by electrolysis.

3. SMOOTH BORE—Making cable pulls easier, both at initial installation and after years of service.

4. EASILY INSTALLED—Lining up is fast and accurate because Transite Ducts combine lightweight, long lengths, simple assembly.

For details and specifications, write for Data Book DS-410, Johns-Manville, Box 290, New York 16, N. Y.

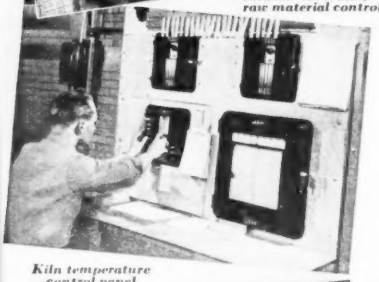
Johns-Manville **TRANSITE DUCTS**

TRANSITE KORDUCT—for installation in concrete

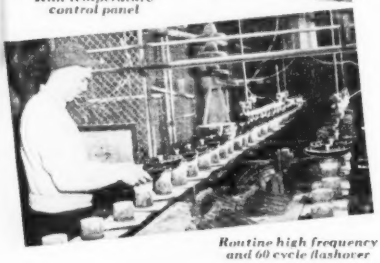
TRANSITE CONDUIT—for exposed work and installation underground without a concrete encasement

The completely modernized Victor plant; over 300,000 sq. ft. of manufacturing space

Ceramic laboratory—raw material control



Kiln temperature control panel



Routine high frequency and 60 cycle flashover

PLANT PERFORMANCE THAT MEANS

Peak Performance

IN HIGH VOLTAGE INSULATORS

HIGH voltage porcelain insulators made at Victor have been acclaimed for their performance on important transmission and distribution systems the world over. This "on-the-job" performance is the result of top performance right in the Victor plant.

Through the various processes of porcelain production . . . mixing, extruding, forming, glazing . . . firing, assembling and testing . . . CONTROL is the watchword. It is this modern plant-wide control which assures high voltage insulators of superior performance—*electrically, mechanically, dimensionally.* For your standard or special insulator requirements, specify Victor!

V

LOOK FOR THIS SYMBOL OF QUALITY

THE MARK OF **V** ENDURING SERVICE

How *This* Trademark benefits YOU

1. MODERN PLANT and EQUIPMENT

Today, Victor is better equipped than ever before to serve electrical utilities and manufacturers throughout the world. For example, in its large, up-to-date plant, Victor now has a battery of four oil-fired tunnel Kilns. Installation of other modern equipment plus advanced techniques enable Victor to offer dependable deliveries on both high and low voltage wet process porcelain.

2. TECHNICAL "KNOW-HOW"

Victor electrical engineers, ceramists, and skilled craftsmen possess the "know-how" that is born of more than half a century of experience making the finest quality porcelain insulators. Even today, there are men in our company who have been in the insulator business at Victor for over forty years. Their knowledge and skill is indispensable in manufacturing insulators of outstanding performance.

3. SUPERIOR QUALITY

Every porcelain insulator produced at Victor is subjected to the most rigid controls throughout its entire manufacture . . . from laboratory tests on every lot of raw materials to the routine flashover with the mechanized electrical tester. Victor insulators easily meet the highest standards of quality established by the National Electric Manufacturers Association and the American Institute of Electrical Engineers.

4. EXPERT ADVICE on SPECIAL DESIGNS

Victor enjoys a large specialty business from manufacturers of transformers, switchgear, protective devices, junction boxes and other electrical equipment. Our engineers and complete laboratory facilities are at your immediate service.

Contact us for consultation on your standard or special porcelain requirements.

VICTOR INSULATORS Inc.

VICTOR, NEW YORK

Look for this trade mark of enduring service

V

UNITED STATES RUBBER COMPANY

LEADERSHIP

in electrical wire and cable value

LEADERSHIP CALLS FOR EXPERIENCE

A century of active participation in the development and manufacture of over 30,000 products, including 70 years in the field of electrical wire and cable, has given our technicians an added skill and knowledge which makes them authorities and specialists in their fields.

LEADERSHIP CALLS FOR COURAGE

So strong and constant has been our desire to produce new and better products, that we have always been the pioneer in our field. Even against odds and at great expense, we have always had the courage to look ahead and to go ahead to new horizons. We have invested in vast scientific projects, have amassed unlimited data and have built great modern research and testing laboratories.

LEADERSHIP CALLS FOR ACCOMPLISHMENT

The result of these efforts have been many amazing products, such as LAYTEX® RU, the world's smallest diameter, lightest weight, natural rubber covered building wire—the new U. S. SERVICE ENTRANCE CABLE with Laytex insulation and Neoprene cover, the first such cable ever approved by Underwriters' Laboratories—the ELECTRIX PLUG, first all-rubber plug ever perfected—USKON, the miracle electrical radiant heat from the ceiling that has completely revolutionized America's heating conceptions.

LEADERSHIP CALLS FOR VALUE

In order to be sure all "U. S." electrical products deliver the utmost performance, there is the close-working team of the U. S. Wholesaler and the U. S. Rubber Salesman. This team is always on the job . . . working out more economical, more practical methods . . . ways to make sure "U. S." products yield the greatest value to purchasers.

LEADERSHIP CALLS FOR VISION

Today, as in the past, "U. S." is still a pioneer in the electrical industry . . . still going forward in its search for scientific discoveries . . . pledging itself to continue the research, the development and the efficiency needed to manufacture new and still better products.

UNITED STATES RUBBER COMPANY • ELECTRICAL WIRE & CABLE DEPARTMENT

1230 Avenue of the Americas • Rockefeller Center, New York 20, N. Y.

UNITED STATES RUBBER COMPANY

BEYOND COMPETITION

Developers and manufacturers of better electrical wires and cables for every need

LAYTEX RU—the world's smallest diameter, lightest weight natural rubber covered building wire.

NEOLAY RU—with Laytex insulation *plus* Neoprene. Nylon cover makes pulling 5 times easier.

LAYTEX RUW—the building wire with the insulation resistance that *increases* in wet locations.

CONTROL WIRES—Insulated with Laytex RU for greater circuit integrity.

NEOPRENE COVERED SERVICE ENTRANCE CABLE—Flame-retardant, moisture resistant—the first ever accepted by Underwriters' Laboratories, Inc.

MUNICIPAL SIGNAL CABLES—Insulated with Laytex RUW for maximum moisture-resistance.

AUTOMOTIVE CABLE SETS

BATTERY SEPARATORS

USEX NON-METALLIC—Finest non-metallic sheathed cable ever made, incorporating the extra protection of Laytex Insulation.

POWER CABLES—of every description, including Neolay Aircraft Wire.

ALUMINUM WIRES AND CABLES—U. S. Rubber introduced insulated aluminum conductors.

UNDERGROUND CABLES—The famous Grizzly line of tough cables.

ELECTRIX PLUGS—U. S. Rubber was a pioneer in the development of soft rubber plugs for cord sets.

ROYAL MASTER PORTABLE CORDS and many other types of electrical wires and cables.

ROYAL MINING MACHINE AND LOCOMOTIVE CABLES—Tested seven different ways to insure complete dependability.

USKON—ELECTRICAL RADIANT HEAT FROM THE CEILING

UNITED STATES RUBBER COMPANY • ELECTRICAL WIRE & CABLE DEPARTMENT

1230 Avenue of the Americas • Rockefeller Center, New York 20, N. Y.

NATVAR 400

helps Distribution Transformers *Take Abuse!*

Natvar

Natvar Products

- Varnished cambric—straight cut and bias
- Varnished cable tape
- Varnished canvas
- Varnished duck
- Varnished silk
- Varnished special rayon
- Varnished Fiberglas cloth
- Silicone coated Fiberglas
- Varnished papers
- Slot insulation
- Varnished tubings and sleevings
- Varnished identification markers
- Lacquered tubings and sleevings
- Extruded vinyl tubing and tape
- Extruded vinyl identification markers

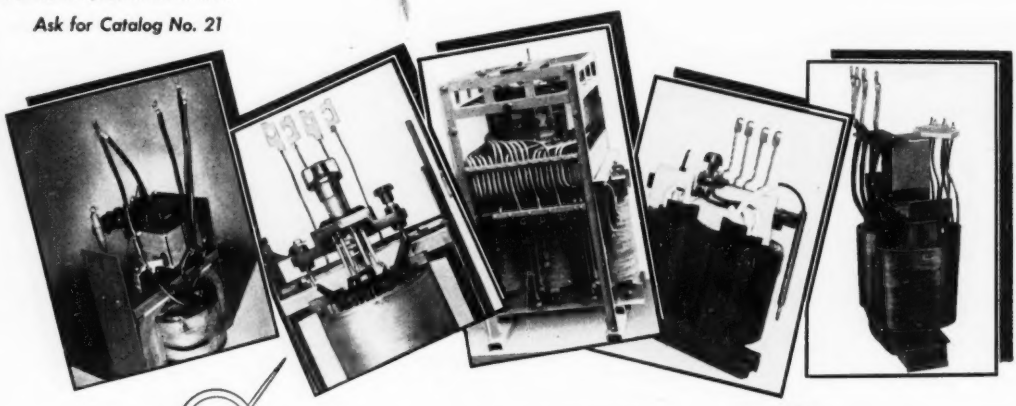
Ask for Catalog No. 21

Utilities today are doing an outstanding job of keeping up with the relentlessly increasing demand. In the race to serve wider areas, and areas of doubled density, distribution transformers have had to handle loads far in excess of rated capacity for long periods without interruption of service.

Principal manufacturers of distribution transformers here and abroad have standardized on Natvar 400 Extruded Vinyl Tubing and tape to insulate and protect leads, because of its high resistance to both *heat and oil*. Approved for continuous operating temperatures of 105°C. Natvar 400 stays flexible indefinitely even when immersed in hot oil. In addition, it is tough, elastic and has excellent resistance to abrasion and tear.

These same properties of Natvar 400 make it ideal for flexible motor leads, for shrink fit protection over splices and pothead leads and for other applications—with great savings in material and labor costs, and reduced waste.

Natvar 400 and other Natvar flexible electrical insulating materials are available for immediate delivery, either from wholesalers' stocks or direct from our own. Full data on request.



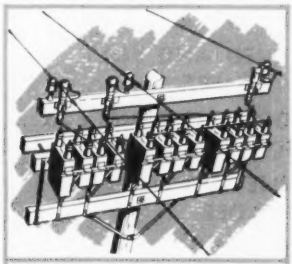
THE NATIONAL VARNISHED PRODUCTS Corporation

TELEPHONE
RAHWAY 7-2171

CABLE ADDRESS
NATVAR: RAHWAY, N. J.

221 RANDOLPH AVENUE ★ WOODBRIDGE NEW JERSEY

...for Topnotch Performance!



Capacitors provide the quickest and most economical means of relieving system overloads and improving voltage conditions where low power factor loads prevail. Capacitors may be obtained from stock, and installed costs are low... less than $10 per Kvar.

Moloney Capacitors are built to the highest standards of quality to assure the excellence of performance that is expected of any product bearing the name Moloney. Reliability of performance is insured by high factor of safety in design, expert workmanship, careful processing and thorough testing.

Individual capacitor sections are wound of aluminum foil and pure kraft insulating papers. Winding is done under controlled temperature and humidity conditions to assure uniformly wound, wrinkle-free sections.

Sections are individually tested prior to assembly into complete capacitor packs. Multi-layer major insulation is placed in the case, and then the assembled pack is inserted. Sections are then connected in parallel groups and groups are connected in series, with a discharge resistor across each group. The cover, with the bushings already installed, is then welded into place completing the case.

The capacitor is now ready for drying and filling with Askarel. Moisture and air are removed by thermo-vacuum treatment, following which non-inflammable Askarel is used to impregnate the capacitor pack and to completely fill the case. Next the filler openings are sealed off and the capacitor is pressure tested for leaks. The capacitor is then given its final electrical tests and packed for shipment.

ME49-9

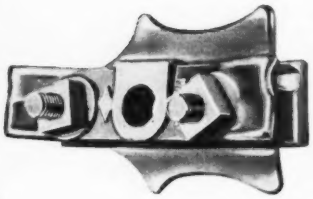
MOLONEY ELECTRIC COMPANY

Sales offices in all principal cities

FACTORIES AT ST. LOUIS 20, MO., AND TORONTO, ONTARIO, CANADA

POLE HARDWARE SPECIALTIES

M. I. F. CABLE-MESSENGER CLAMPS

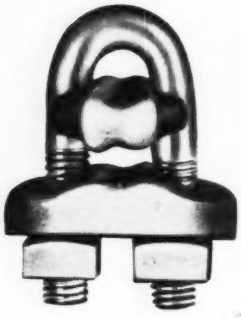


—in several sizes to *meet all conditions of aerial cable construction — accommodating* cables from 2 lbs. to 16 lbs. per ft., messengers from 3/16" to 5/8" diameters and providing adequate clearance from, and firm bearing on, pole. Malleable castings of rugged construction with messenger grooves belled out at ends to permit easy turns.

M. I. F. GUY HOOKS

—in four sizes for practically all down-guying where angle does not exceed 60°. Malleable castings — corrosion resistant. Ratings determined by strength of thru bolt. M.I.F. Guy Hooks provide a generous radius to accommodate strand, permit easy installation of strand and offer positive connection to pole. *Strongest construction at lowest cost.* Over 3,000,000 in use.

M. I. F. GUY CLAMPS



— with the efficient tilting U-bolt feature provide *far more holding power for less* cost, developing on the average over 100% of the rated breaking strength of the strands for which recommended. Each clamp accommodates a range of strand sizes. These facts, combined with low weight per unit, effect important savings in handling and inventory. Also furnished with stainless steel U-bolts and nuts.

M. I. F. Pole Hardware Specialties are now specified by Electric Light & Power Companies constituting more than half the operating capacity of the United States and Canada. Millions of installations and consistent repeat orders attest to their **field tested,** satisfactory performance.

Each M. I. F. fitting is a product of research and development, designed to meet specific industry needs more economically and functionally than ever before. New Pole Hardware which will offer better performance at lower cost is continually under development.

Whether you need stock items, or special products in quantity, you will find M. I. F. ready to assist you.

In addition to items illustrated, we offer:

BOLT EYES & EYE NUTS

CURVED AND FLAT WASHERS

CROSS ARM GAINS FOR SQUARED & ROUND ARMS

JENNE GUY STRAND HOLDER

POLE MOUNTS

POLE EYE PLATES

TRANSFORMER MOUNTING PLATES

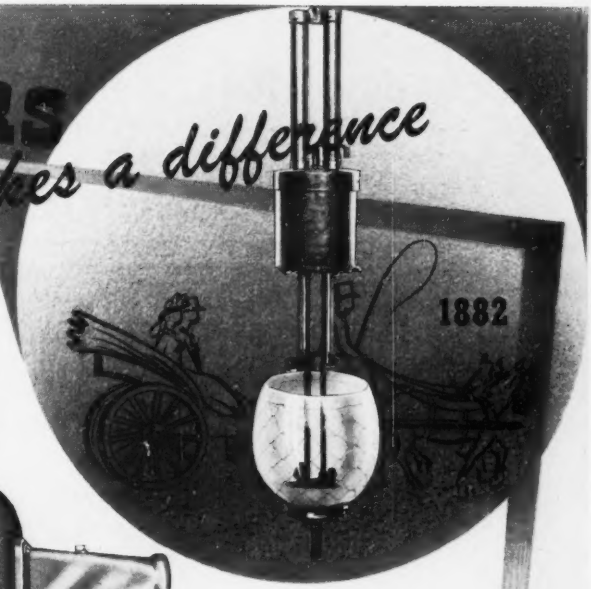
OTHER SPECIALTIES

Write for detailed specifications and samples.

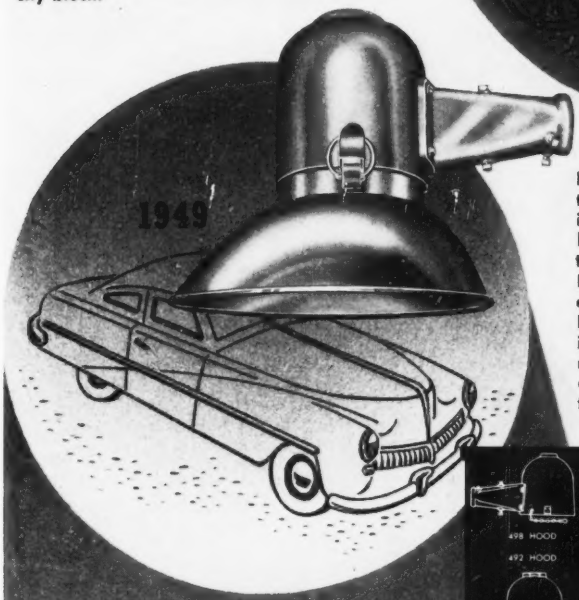
N. Y. Office: 30 Church St., N. Y. C.
Canadian Mfr. & Dist: LINE & CABLE ACCESSORIES, Ltd., Toronto

MALLEABLE IRON FITTINGS CO.
POLE HARDWARE DEPARTMENT
BRANFORD CONNECTICUT

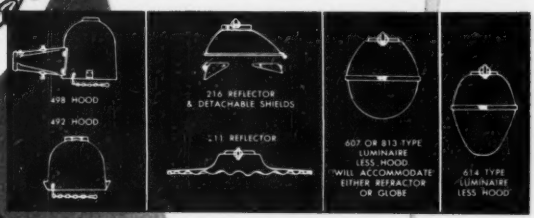
67 YEARS *makes a difference*



PEMCO, a pioneer in the manufacture of Street and Highway Lighting Equipment, today enjoys the position of being the oldest Street Lighting manufacturer in America operating under its original name and management. Since its organization in 1882 PEMCO has grown from a small one story building to a modern plant which now covers practically an entire city block.



From the days of the carbon arc light down through the years of the evolution of modern incandescent Street Lighting Fixtures, PEMCO has borne its share of the responsibility for the progress of Street Lighting. PEMCO Luminaire No. 306 (illustrated) is an example of the latest development in modern Street Lighting. Detachable reflector and shields, interchangeable on a variety of hood styles, make these Luminaires economical to install and maintain. Careful engineering guarantees maximum efficiency.



For information on PEMCO's complete line of Street and Highway Lighting Equipment request PEMCO General Catalog No. 90.

PEMCO

Low-cost upkeep and replacement is paramount in modern Street Lighting practice. Interchangeable parts not only lessen the need for warehousing large stocks of maintenance equipment, but simplify changeover from one type of luminaire to another. Long-range planning with PEMCO Interchangeable Luminaires will pay big dividends in reduced future costs.

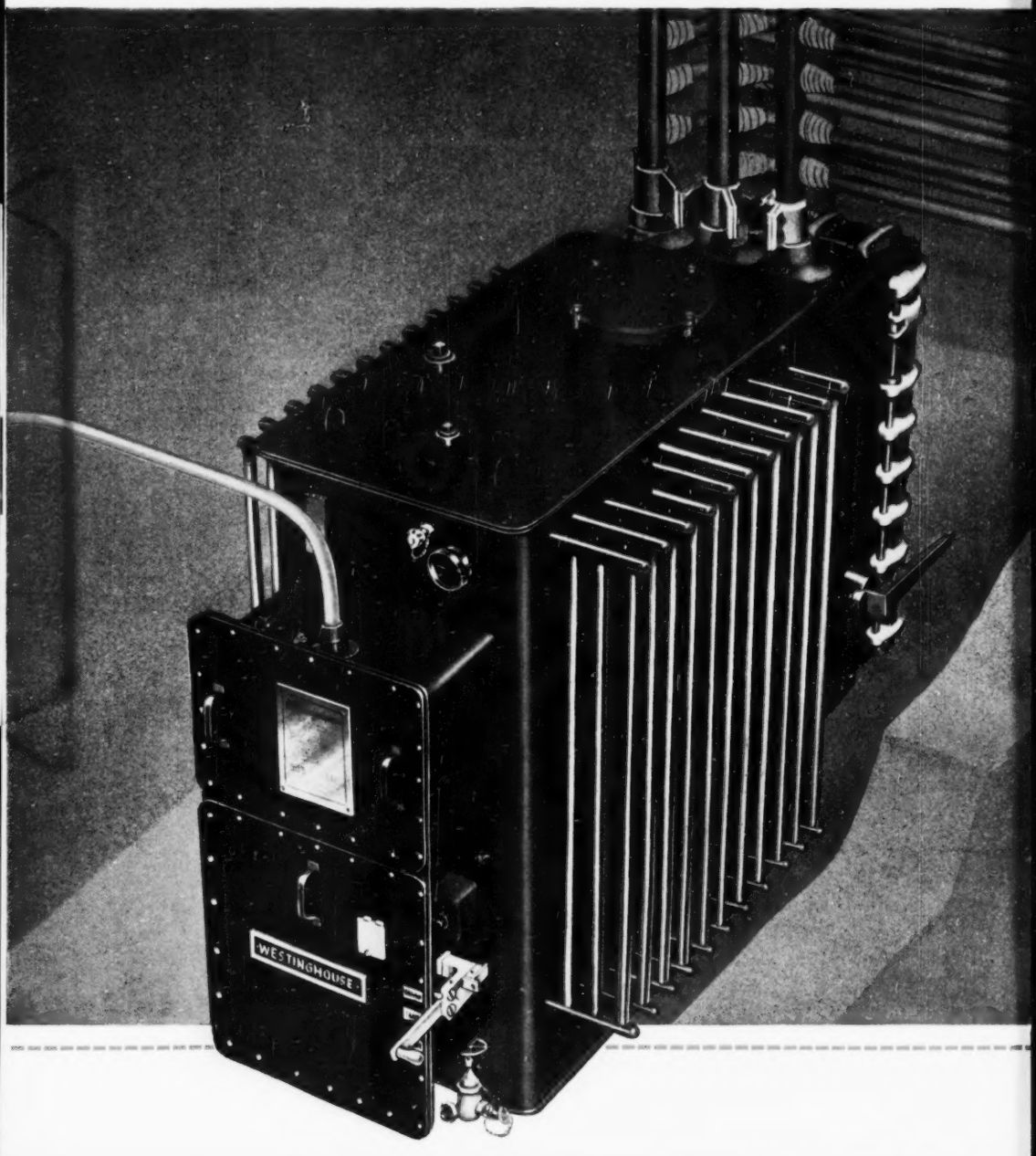
PHILADELPHIA ELECTRICAL & MFG. CO.

1200-36 N. 31ST STREET, PHILADELPHIA 21, PA.

SALES OFFICES IN PRINCIPAL CITIES

YOU CAN BE **SURE**.. IF IT'S

Westinghouse



Now you can lower network costs with a Westinghouse

STANDARD-TYPE transformer

New Features, New Ratings, New Service in Standardized Designs

The new Westinghouse Network Transformers are designed to make the use of standard units both practical and economical. Now you can eliminate individual engineering and meet your needs better than ever before.

The many "plus" features of Westinghouse standard-type, liquid-filled Network Transformers include:

Liberal Clearances between conductors to insure continuity of service;

Continuous Windings with sliverless copper;

Welded Cover providing Sealedaire dependability;

High-voltage Terminal Chamber with ample space for making cable connections in low vault;

Low-voltage Bushings that can be replaced without removing cover;

Undercoating of base to reduce maintenance and lengthen life.

In addition, you can stock standardized parts; delivery time is reduced to a minimum; and cost is less because the engineering has already been done. And now, two new standard ratings—150 and 225 kva—give you all the advantages in six liquid-filled units from 150 to 1,000 kva.

Westinghouse leadership, which developed network distribution and is constantly pioneering improvements, offers a sales and engineering service to assist you in applying the transformers for maximum service and economy both for enlarging established systems and in new applications.

Transformer engineers are always at your service via your nearest Westinghouse office. Write for B-4082 to Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pa. J-70528

THE SAFEST TRANSFORMER EVER BUILT!

Yet another step forward in network distribution is the new Westinghouse STANDARD SUBMERSIBLE DRY-TYPE Transformer. No liquids to leak, burn, explode, fume or require attention; built with Class H insulation; sealed nitrogen-tight by welding.

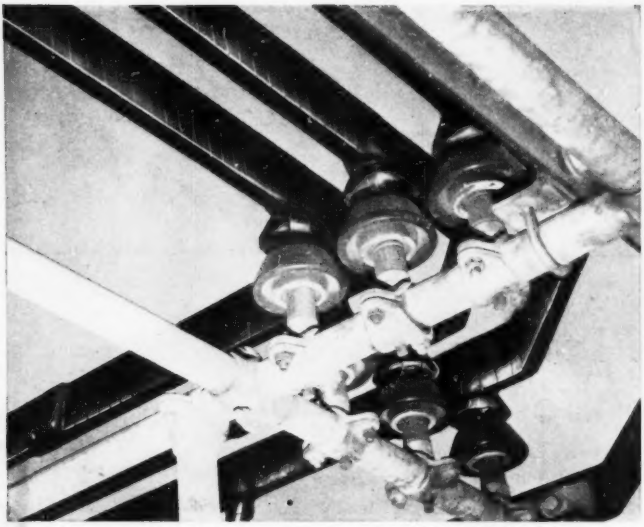
The Westinghouse Network Transformer line, to which this unit is the latest addition, also includes:

STANDARD VENTILATED DRY-TYPE units, for use where not subject to submersion;

STANDARD LIQUID-FILLED units (oil or Inerteen) for submersible service.

Westinghouse

NETWORK TRANSFORMERS



OUTDOOR BUS INSTALLATION is exposed to extreme temperature, sunlight, moisture and corrosive gases. Yet the insulating material, "SCOTCH" No. 33 Electrical Tape, on the bars and leads is unaffected.

Get two-way protection with this NEW tape

The tough plastic backing on "SCOTCH" No. 33 Electrical Tape gives a high dielectric strength plus sturdy resistance to weathering and corrosion—making an efficient insulation for practically every type of electrical job.

Give this remarkable NEW "SCOTCH" Electrical Tape a try. You'll find it's easier to apply than other materials—gives you a neater, more compact job. Write Dept. EW-5 for complete information and a free sample.

Quick facts about "SCOTCH" No. 33 Electrical Tape

- **HIGH DIELECTRIC STRENGTH**—insulates perfectly against charges of over 7,000 volts.
- **TOUGH**—plastic backing resists abrasion, water, acids, alkalies, alcohols.
- **THIN CALIPER**—only .007" thick, requires less room in all insulation work.
- **STRETCHY**—conforms snugly to uneven surfaces, irregular shapes.
- Carries the seal of Underwriters' Laboratories.

Standard roll ¾ in. wide and 66 ft. long. Each roll individually packed in a handy tin.

ANOTHER 3M COMPANY PRODUCT

Made in U. S. A. by

MINNESOTA MINING & MFG. CO., Saint Paul 6, Minnesota

General Export: DUREX ABRASIVES CORP., *New Rochelle, N. Y.*
In Canada: CANADIAN DUREX ABRASIVES LTD., *Brantford, Ontario*

HARPER

NON-FERROUS AND STAINLESS STEEL Everlasting Fastenings OFFER

13 Reasons

FOR USE IN YOUR PRODUCT over common steel...

1. Resistance to Rust and Corrosion
2. Resistance to High Temperatures
3. Non-Magnetic
4. Non-Sparking
5. Re-Useable
6. Attractive Appearance
7. Easy to Clean
8. High Strength
9. Long Life
10. Lower Ultimate Cost
11. Resistance to Fatigue
12. Easy to Plate or Finish
13. Resistance to Abrasion and Wear

OVER 6000 ITEMS IN STOCK

Bolts, Nuts, Screws, Washers, Rivets and Accessories in Brass, Bronzes, Copper, Monel and Stainless Steels.

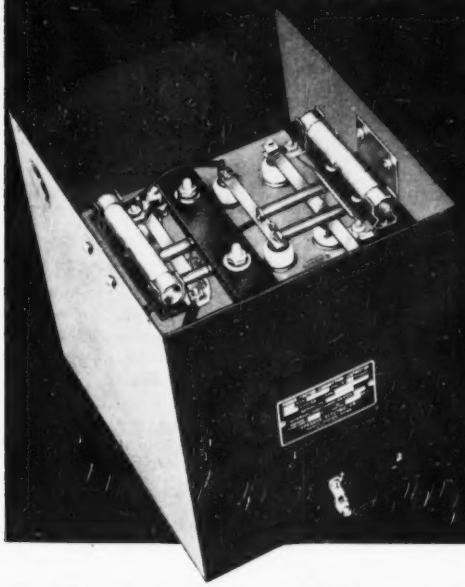
Write for Catalog giving blue print drawings, dimensions, threads, heads and sizes of each item.

THE H. M. HARPER COMPANY
General Offices and Plant
Morton Grove, Illinois
(Suburb of Chicago)
New York Office and Warehouse
200 Hudson Street, New York 13

Branch Offices: Atlanta, Cambridge, Cincinnati, Cleveland, Dallas, Denver, Detroit, Grand Rapids, Los Angeles, Milwaukee, Philadelphia, Pittsburgh, St. Louis, San Francisco, Seattle, Toronto (Canada).

HARPER

On-the-spot POWER FACTOR CORRECTION . . . *at minimum cost!*

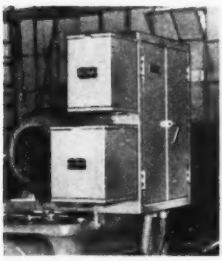


NEW UNITS 33% SMALLER . . . THANKS TO VITAMIN Q®

This exclusive Sprague capacitor impregnant makes a startling reduction in the size of 460 and 575 volt capacitors. A 15 KVAR unit is now no larger than an old style 10 KVAR capacitor.

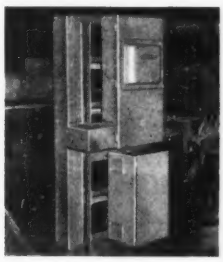
SPRAGUE CAPACITORS

Reduce power bills . . . Cut wiring, transformer and switchgear costs in new installations . . . Avoid rewiring



INEXPENSIVE SERVICE FOR TWO MOTORS

Two Sprague Unit-Cell Capacitors, one of 6 KVAR serving a 25 h-p motor and the other of 4 KVAR serving a 15 h-p motor, provide exact correction where it is most effective—across the motor terminals.



INSTALLATION RIGHT WHERE NEEDED

This neat 100 KVAR 460 volt, 1 phase, Sprague rack is connected across the load side of a synchro-break contactor supplying a 350 KVA seam welder. It provides maximum P-F improvement at minimum cost.

DON'T overlook the most effective, easiest and least expensive way to increase the circuit and feeder capacity in thousands of instances. Correct low power factor troubles, by simply installing Sprague Unit-Cell Capacitors right at the terminals of low P-F load without additional expense for switches and fuses. Sprague Capacitors give you the exact correction you need right where it saves you most.

Available in standard ratings of 1, 2, 3, 4, 5, 6, 8, 10 and 15 KVAR at 230, 460, or 575 volts.

WRITE FOR FREE BOOKLET — Power Factor Improvement Problems are *easy* with the helpful data and installation hints in Sprague Manual 50B. Write for yours today!

SPRAGUE ELECTRIC COMPANY, NORTH ADAMS, MASSACHUSETTS

ALWAYS SPECIFY..

TRANSFORMER BUSHINGS

by

Illinois

Illinois' thorough control of production methods insures porcelain bushings of high dielectric and great mechanical strength, with utmost accuracy in the control of dimensions. Internal stress is prevented through careful drying and firing at scientifically controlled temperature levels.

Bushings can be standard glaze or radio interference-proof glaze. Dry type bushings are produced for all voltages up to 34.5 kv. Gasket seats are smooth, and ground when required.

EXACT DIMENSIONS

COMPLETE UNIFORMITY

HIGH DIELECTRIC STRENGTH

HIGH MECHANICAL STRENGTH

®

ILLINOIS
ELECTRIC PORCELAIN CO.

MACOMB, ILLINOIS

NEED A TIGHT SEAL FOR CABLE ENTRANCES, SERVICE BOXES, CONDUIT ENDS?

...then use

Johns-Manville

DUXSEAL

DUXSEAL is the "Handy Andy" of sealing compounds for closing up conduit and duct ends . . . for sealing openings around wires and service boxes . . . for quickly plugging up drill holes in foundations.

Stays plastic—It stays soft indefinitely, can be used in any weather just as it comes from the package.

Stays tight—It adheres to duct walls and cables, but gives with the expansion or contraction of the wire.

Stays insoluble—It is unaffected by ground waters, gases and low heats, will not slump, melt or run.

Stays re-usable—It can be re-used to form a new *tight* seal after years in service.

Tight seals for other electrical uses

J-M TRANOLSEAL . . . for use with electrical equipment using dielectric oils.

J-M UNISEAL . . . for caulking against weather and humidity. Resists temperatures up to 180 F.

For further information on any of the above sealing compounds, write to Johns-Manville, Box 290, New York 16, N. Y.

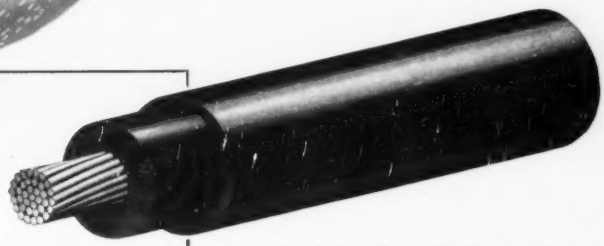
JM

Johns-Manville SEALING COMPOUNDS

G-E Super Coronol is the only rubber-type cable that is recommended without qualification for operation at 80-C copper temperatures for all voltages up to 15,000.

And this means higher current-carrying capacity, weight saved, a smaller size. Super Coronol carries up to 6 per cent more current below 8000 V than any other rubber-type cable; 14 per cent more, above 8000 V.

But this high efficiency is only part of the story. We are confident that service life at 80 C will be longer than that of other rubber-type cables operated at their *lower* recommended temperatures. Reason is that Super Coronol's butyl-base insulation is essentially inert. This extreme stability defies weather aging, ozone, heat.



TEST GUARANTEES NOW RAISED ABOVE INDUSTRY STANDARDS

So conclusively have all tests proved the superiority of Super Coronol's insulation that we have now raised our *guaranteed* test values above IPCEA and ASTM requirements, giving industry a new standard for rubber-type cable.

SUPER CORONOL EXCEEDS INDUSTRY REQUIREMENTS

PHYSICAL CHARACTERISTICS	IPCEA REQUIREMENTS	SUPER CORONOL
Original		
Tensile strength, lb sq in.	450	500
Per cent elongation	250	400
Set in 2-in. test piece, in.	$\frac{1}{2}$	$\frac{1}{2}$
After 7 days in Geer oven		
Tensile strength, lb sq in.	400 } 70 C	400 } 80 C
Per cent elongation	200 } 70 C	250 } 80 C
Ozone resistance	3 hours	4 hours
ELECTRICAL CHARACTERISTICS		
Insulation resistance, K value	5280	15840
Power factor, per cent	5	4
Dielectric constant	5	5
COPPER TEMPERATURE		
Up to 8000 volts	75 C	80 C
Above 8000 volts	70 C	80 C

For a high-voltage cable that handles like other rubbers and performs much better, specify Super Coronol. It's made in several constructions. Additional data are given in the bulletin "Some Facts about Super Coronol." Ask your local G-E office for GEA-1788, or write *Section W31-527, Construction Materials Dept. General Electric Co., Bridgeport 2, Conn.*

SUPER CORONOL

gives you

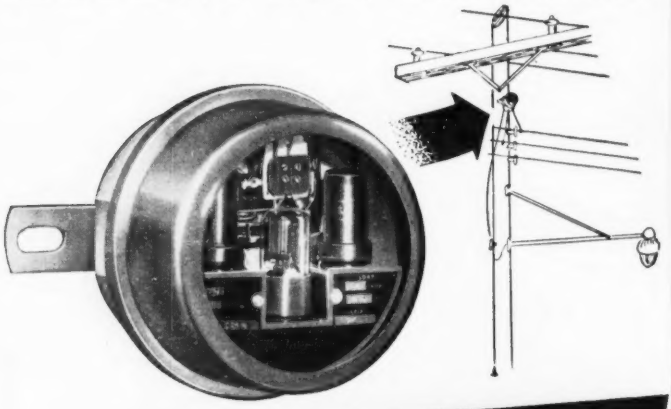
***both* longer cable life**

***and* greater load capacity**

GENERAL ELECTRIC

FISHER-PIERCE

PHOTOELECTRIC STREET LIGHT CONTROL



AUTOMATIC CONTROL For Multiple or Series Lighting

FISHER-PIERCE CONTROLS OFFER:

A. Improved Quality of Lighting Service — Fisher-Pierce controls give guaranteed turn-on of street lighting when it is needed. Only a photoelectric control can give positive light control independent of conditions of daylight, weather, or climate.

B. Lower Cost Lighting — Separate street lighting circuits may be entirely eliminated. Individual street lights, or lights for an entire street can be connected directly to the 120 or 230 volt distribution lines.

C. Reduces Maintenance Cost—Fisher-Pierce units have a conservatively designed electronic circuit resulting in nominal tube life of over 20,000 hours. Plug-in construction of the entire chassis permits easy servicing. No resetting is required after power interruption.

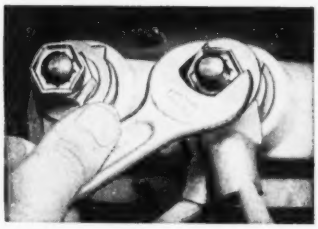
SOME OF THE OUTSTANDING DESIGN FEATURES ARE:

1. Contact capacity of 500 or 3000 watts of incandescent lamp load.
2. Completely weather-proof enclosures.
3. Mounting suitable for either cross-arm or pole surface.
4. Fifteen second time delay to prevent false operation from lightning, passing automobile headlights, or other light transients.
5. Models for 120 and 230 volts, 50-60 cycles.

Also available are Special Models for Outdoor Signs, Billboards, Aircraft Obstruction Lights and other light control applications. Units can be shipped from stock. Write today for further information.

The FISHER-PIERCE COMPANY, INC.
82 CEYLON ST., BOSTON 21, MASSACHUSETTS

PALNUTS* Keep Terminal connections Permanently Tight



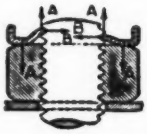
- *Perfect Conductivity*
- *No heating or corroding of contact surfaces*
- *Easy, speedy assembly*

PALNUTS apply on TOP of the regular nuts, holding them to original tightness. Spring washers are eliminated between nut and terminal lug. There can be no backing off of nuts, nor opened spring washers to reduce contact. Instead, full conductivity of the entire nut seat is maintained under severest vibration.

Double-locking PALNUTS are single thread locknuts, made of tempered spring steel or silicon bronze. They are easily, quickly spun on with the fingers and locked with 1/3 turn of a wrench. Require only 3 bolt threads space, are light in weight, low in cost, may be re-used.

PALNUTS are available from stock for every utility requirement. Write for PAL-NUT Manual giving engineering data.

Double Locking Action



Arched, slotted jaws grip the bolt like a chuck (B-B), while spring tension is exerted upward on the bolt threads and downward on the regular nut (A-A), securely locking both.

* *Trademark, Reg. U. S. Pat. Off.*

THE PALNUT COMPANY

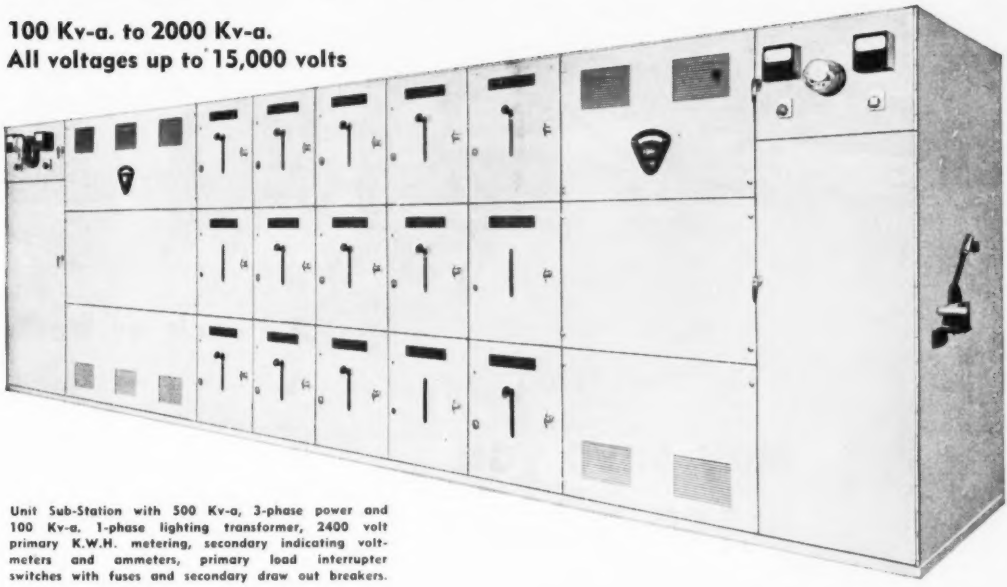
51 Cordier St.
Irvington 11,
N. J.

Modern Unit Sub-Stations

for Indoor Installation with

SORGEL Air-Cooled Transformers

100 Kv-a. to 2000 Kv-a.
All voltages up to 15,000 volts



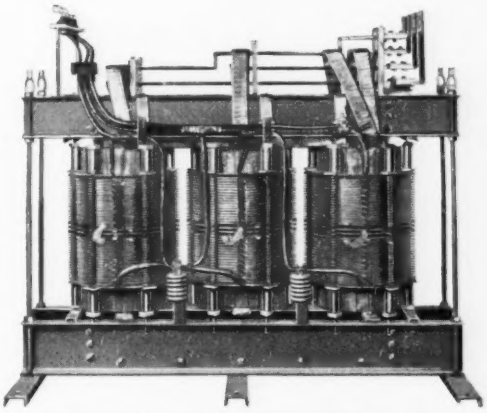
Unit Sub-Station with 500 Kv-a, 3-phase power and 100 Kv-a. 1-phase lighting transformer, 2400 volt primary K.W.H. metering, secondary indicating voltmeters and ammeters, primary load interrupter switches with fuses and secondary draw out breakers.

The complete unit sub-station is shipped in one or more factory-assembled units, completely wired, ready for installation and final connections. This eliminates the necessity for purchasing separately from various manufacturers the transformers, switches, fuses, insulators, circuit breakers and other accessories, and then assembling and connecting them on the job.

The entire sub-station, having all live parts enclosed, can be located in most any convenient place inside the building, without any other enclosure. Containing no oil, there is no need for a fireproof vault.

Maintenance expenses are reduced to a minimum, since there is no liquid to check, replenish or replace.

We also manufacture a complete line of General Purpose Air-Cooled Transformers.
1/4 Kv-a. to 2000 Kv-a. All voltages.



500 Kv-a, 3-phase, 13,800 volt Transformer with enclosure removed illustrates the disc type coil windings. This type of winding is employed for voltages above 5,000 volts. These disc type coils are separated from each other and supported with steatite ceramic insulators. All insulation is Class C and Class B throughout.

Sorgel Electric Co. *The* **PIONEERS** *in the development and manufacturing of Air-Cooled Transformers* **834 W. National Ave., Milwaukee 4, Wis.**

may save you 150 Dollars!

49 CENTS MORE THAN AN UNTREATED CROSSARM . . . that's all the premium you pay to purchase the average crossarm that has been *pressure-treated* with Koppers Creosote . . . that has been protected against decay . . . that will last, on the average, about twice as long as an untreated arm.

Untreated fir crossarms usually last for only 15 or 20 years. Koppers Pressure-Creosoted Crossarms have a life expectancy similar to Koppers Full-Length Pressure-Creosoted Poles. Obviously, by using crossarms that last as long as poles, you can effect substantial savings.

That's not all! If an untreated crossarm, weakened by decay, goes out of service during a storm or at night, it may cost you as much as $150.00 to make the replacement. Not to mention the hazard to linemen . . . the interrupted service . . . the loss of revenue. Yes—from every point of view, it pays to purchase Koppers Pressure-Creosoted Crossarms.

Deliveries of Koppers Pressure-Creosoted Crossarms and Poles are made from conveniently located treating plants.

KOPPERS COMPANY, INC., Pittsburgh 19, Pa.

KOPPERS **PRESSURE-CREOSOTED WOOD**

A touch of zero in the farmer's kitchen

STRAWBERRIES in December! That's just one small pleasure for the farmer who owns a frozen food unit. More important, it preserves fresh meat and farm-grown vegetables and reduces costly marketing trips for food. Refrigeration for the farm . . . gift of electricity!

With the increasing demand for rural electrification, comes the need for efficient pole-line insulation. Hemingray Power Insulators provide the highly efficient and dependable insulation necessary for medium voltage lines.

No. 670 for 12,000-volt lines. The Technical Standards Committee of the Rural Electrification Administration has approved Hemingray Insulators No. 670, No. 680 and No. 514, under the limits of AIEE Specification No. 41-1944 for use on REA lines.

HEMINGRAY
POWER INSULATORS

American Structural Products Company
Muncie, Indiana
Subsidiary of **Owens-Illinois Glass Company**

"KNOW" house

Line Material's new Short-Circuit-Testing Laboratory, now nearing completion. One of the most up-to-date laboratories in the country for testing power apparatus under heavy fault currents. This latest addition to L-M's research facilities anticipates the industry's requirements for equipment to handle heavier loads.

Ready soon... THIS GREAT NEW ADDITION TO LINE MATERIAL RESEARCH FACILITIES

With the growth of distribution line loads, power companies will require heavier equipment to handle these heavier loads. Foreseeing the trend, Line Material engineers began, five years ago, to plan a new and greater laboratory that would make possible actual tests, under heavy fault-current conditions, of the new and heavier equipment that power companies would require.

Today this new laboratory is nearly completed. When it is, L-M will be one of only four companies in the country having such laboratories. And this laboratory is noteworthy because of some unique features in its design and equipment.

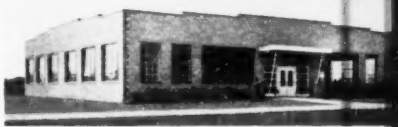
Here, for example, you will find: the world's largest high speed short-circuit generator... a unique explosion-proof indoor test cell, with heavy reinforced concrete walls and bullet-proof windows for observation... intricate automatic controls, with oscillograph and photographic equipment to assure accurate records of tests.

For years Line Material has been a leader in distribution equipment research and development. Its engineers have always prided themselves on their company's facilities for obtaining exact *knowledge* of product performance. This great new "KNOW" House will contribute substantially to the development of new and heavier equipment to meet the growing needs of the industry.

SOON: Line Material appreciates the wide interest shown in this new laboratory, and hopes that it may be opened to qualified visitors some time this summer. A special welcome will be extended to the many people who have contributed their suggestions, counsel, and help, and whose generous cooperation is deeply appreciated.

Other new facilities to serve you

Line Material's expansion is based on our policy of meeting our customers' needs. For faster delivery, new warehouses have been opened in Cambridge, Harrisburg, Cincinnati, Minneapolis, and Dallas. A new office building at East Stroudsburg adds facilities for serving the East. Pictures show some other recent additions.



New engineering building at Kyle Company division provides a larger test laboratory, experimental model shop, and engineering department space, for research and development on reclosers, sectionalizers and other Kyle products.

At Birmingham, Alabama, Southern Line Material has expanded its pole line hardware manufacturing into a new plant four times as large, to help meet the growing demands of the South.

New plant at Kansas City provides modern facilities for the manufacture and hot-dip galvanizing of pole line hardware and line construction specialties.

7127

LM

LINE MATERIAL Research

Completely Tested and Coordinated Distribution Equipment

FRANKEL Economy FLEXILUG* Line Expands!

*Underwriter Approved

2 new sizes added Larger FLEXILUG Smaller

A WIDER RANGE OF SIZES!

The new small FLEXILUG takes all wire sizes #14 through #8 . . . is smaller, fits in tighter spots than the previous small sized Flexilug. The new, large FLEXILUG takes all wire sizes from 250 mcm. to 500 mcm. Both new sizes give you the famed FRANKEL engineering . . . at costs lower than ever before! Five FLEXILUG sizes now take from #14 to 500 mcm. wire, and give equally dependable service on stranded, flexible or solid wire.

●

COMPARE THESE 5 EXTRA ADVANTAGES!

- ★ 100% conductivity in all current carrying parts.
- ★ 100% commercial thread on nut and set screw . . . a non-stripping combination.
- ★ 100% wire protection with rigid pressure distributing shoe; screw never touches wire.
- ★ Seamless drawn tube housing gives 150% strain safety factor.
- ★ Cadmium plating eliminates heating caused by formation of high-resistant copper oxide, and permits use with aluminum and steel cables.

A quality lug . . . at a practical price

engineered

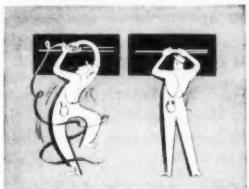
Materials selected for each FLEXILUG part are determined by the exact service requirement for each part.

All parts are interlocked into one integrated unit . . . they cannot work loose or drop out.

FLEXILUGS are precision-built to make up tight and stay tight . . . get tough jobs done faster, easier.

●

Keep Frankel Flexilugs handy . . . you'll use them every day!



It's easier and faster when you use Frankel Solderless Connectors

Send for May 1, 1949 revised price list

SOLD THROUGH LEADING WHOLESALERS ONLY

Frankel Solderless Connectors

FRANKEL CONNECTOR CO.

27 VESTRY ST. • NEW YORK 13, N. Y.

42 YEARS OF KNOW-HOW IN SOLDERLESS CONNECTORS

EISLER TRANSFORMERS

STANDARD & SPECIAL

for

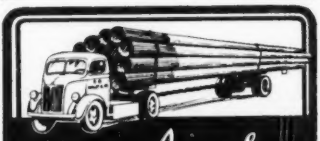
POWER
LIGHTING
HEATING
WELDING
ELECTRIC FURNACES
PHASE CHANGING
ETC.

FROM 1/4 TO 500 KVA UP TO 15,000 VOLTS

EISLER TRANSFORMERS ARE BUILT STRICTLY TO N.E.M.A., A.S.A. AND A.I.E.E. STANDARDS

Write for Special Catalog

EISLER ENGINEERING CO., INC
CHAS. EISLER, PRES.
769 South 13th Street Newark, N. J.



Haleys

CEDAR POLES
FIR CROSS ARMS

Quick Truck Shipments from our Ohio yard

●

Also yards at Minneapolis and Haley, Idaho

R. G. HALEY & CO., Inc.
SPITZER BLDG.
TOLEDO 4, OHIO

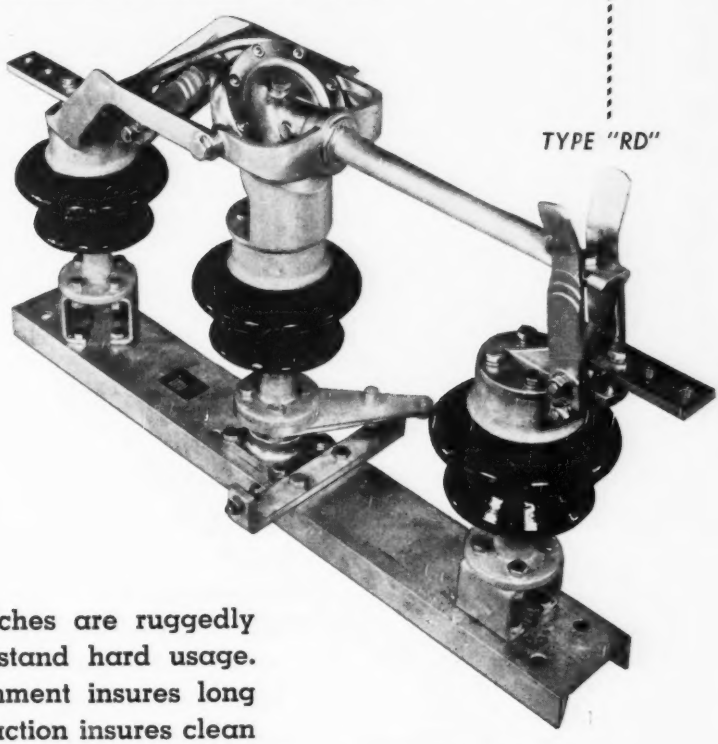
POWERCRAFT

NEW · · · RUGGED

VERTICAL BREAK AIR SWITCHES

with ROLLING DISC ACTION

- POSITIVE ALIGNMENT
- OPERATIONAL EASE
- POSITIVE WIPING ACTION



TYPE "RD"

THESE switches are ruggedly built to withstand hard usage. Positive alignment insures long life. Wiping action insures clean contact surfaces. All contacts are solid silver alloy to solid silver alloy (both ends of switch). All current carrying members are hard drawn bus bar copper. All bearings are anti-friction type.

- For a rugged switch, for a "tough" installation on voltages from 7.5 to 230 K.V. and from 600 to 1200 amps., call on us and we will give you complete information in bulletin 4901.

POWERCRAFT CORPORATION

MAIN OFFICE and FACTORY 2215 DeKALB ST. - ST. LOUIS 4, MO.

NEW AIR-COOLED DISTRIBUTION TRANSFORMERS

POLE MOUNTED — OUTDOOR — ALL-PURPOSE — INDOOR — WALL MOUNTED

MARCUS SCORES AGAIN IN THE FIELD OF AIR COOLED TRANSFORMERS

AIR-COOLED TRANSFORMERS
1 to 2,000 KVA up to 15,000 Volts to meet Individual Requirements

- DISTRIBUTION
- GENERAL PURPOSE
- PHASE CHANGING
- ELECTRIC FURNACE
- RECTIFIER
- WELDING
- MOTOR STARTING

From a Pioneer in the field comes a new distribution transformer—AIR COOLED, DRY TYPE. No hazardous oil or toxic liquids to fuss or bother with. The use of superior class B and C heatproof insulation such as fibre-glass, mica, porcelain, new Johns-Manville Quinterra and similar inorganic material results in a transformer that can withstand the overloads that normally would damage an ordinary class A (cotton and paper) insulated oil filled unit. The entire transformer element is seal protected against oil, acids, moisture, etc., and is housed in a sturdy, scientifically ventilated, weatherproof case which conforms with all applicable EEI-NEMA construction standards. This extremely versatile transformer can be used outdoors, pole or platform mounted or indoors at the load center, mounted wherever convenient with no expensive fireproof vault required.

Currently available in sizes to 100 KVA, voltages to 5000 V.

COMPETITIVE PRICES • GOOD DELIVERIES

WRITE FOR BULLETIN #49-ACO

MTC

Representatives in Principal Cities

MARCUS TRANSFORMERS CONFORM TO THE STANDARDS OF N.E.M.A. AND A.I.E.E.

MARCUS TRANSFORMER CO.
INC.
30 MONTGOMERY STREET
HILLSIDE 5, NEW JERSEY

PIONEERS IN THE FIELD OF AIR-COOLED TRANSFORMERS

wet process porcelain
ENGINEERED BY GENERAL CERAMICS

A DEPENDABLE SUPPLY — General Ceramics offers a reliable supply of uniformly high quality wet process porcelain electrical insulators. Competent engineering cooperation is always available to help work out your designs.

Available in Wet Process Porcelain or Steatite, Metallized if Needed

Use General Ceramics Wet Process Steatite for extra mechanical strength. Can be tapped without metal inserts. Also obtainable metallized to specification. ESTIMATES WITHOUT OBLIGATION.

General CERAMICS and STEATITE CORP.
KEASBEY • NEW JERSEY

Makers of Steatite, Titanates, Zircon Porcelain, Alumina, Light Duty Refractories, Chemical Stoneware, Impervious Graphite, Ferrites, Coaxial Cable

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Probably no other organization is as well equipped as McGraw-Hill to solve the complicated problem of list maintenance during this period of unparalleled change in industrial personnel.

McGraw-Hill Mailing Lists cover most major industries. They are compiled from exclusive sources, and are based on hundreds of thousands of mail questionnaires and the reports of a nation-wide field staff. All names are guaranteed accurate within 2%.

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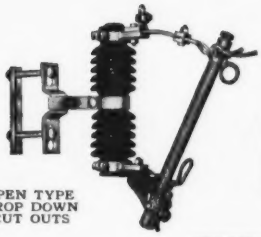
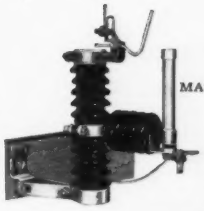


OPEN TYPE DROP DOWN CUT OUTS

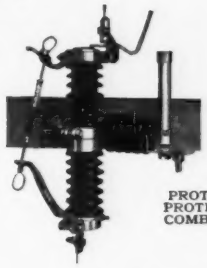
PROTECTOLINK CUTOUTS



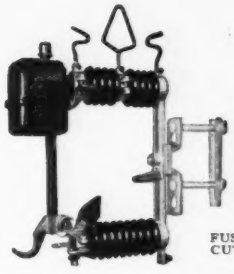
MATTHEWS PROTECTOGAPS

MATTHEWS PRODUCTS

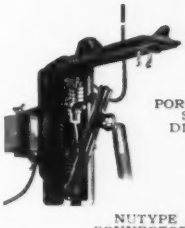
YOU will find in all Matthews Products, good engineering and design, combined with top quality materials. Shown here are some of these products which have been widely accepted and are giving excellent service year in and year out. The constantly increasing acceptance of Matthews Products has been a challenge to our organization to meet these demands and to do so in the most economical manner. With this in view we have expanded and modernized our facilities so as to reduce production costs and pass these savings along to you. We are now occupying our larger new modern offices and factory which are equipped to give you better than ever service. We cordially invite you to visit our new home when you are in St. Louis.



PROTECTOGAP PROTECTOLINK COMBINATIONS



FUSELESS CUTOUTS

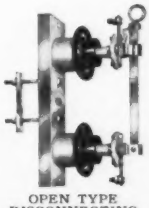


PORCELAIN HOUSED SOLID BLADE DISCONNECTING SWITCHES

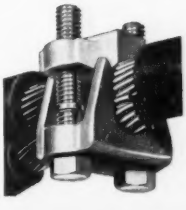
NUTYPE CONNECTORS

Write for catalog describing all Matthews Pole Line Protective Devices

PORCELAIN HOUSED CUTOUTS



OPEN TYPE DISCONNECTING SWITCHES

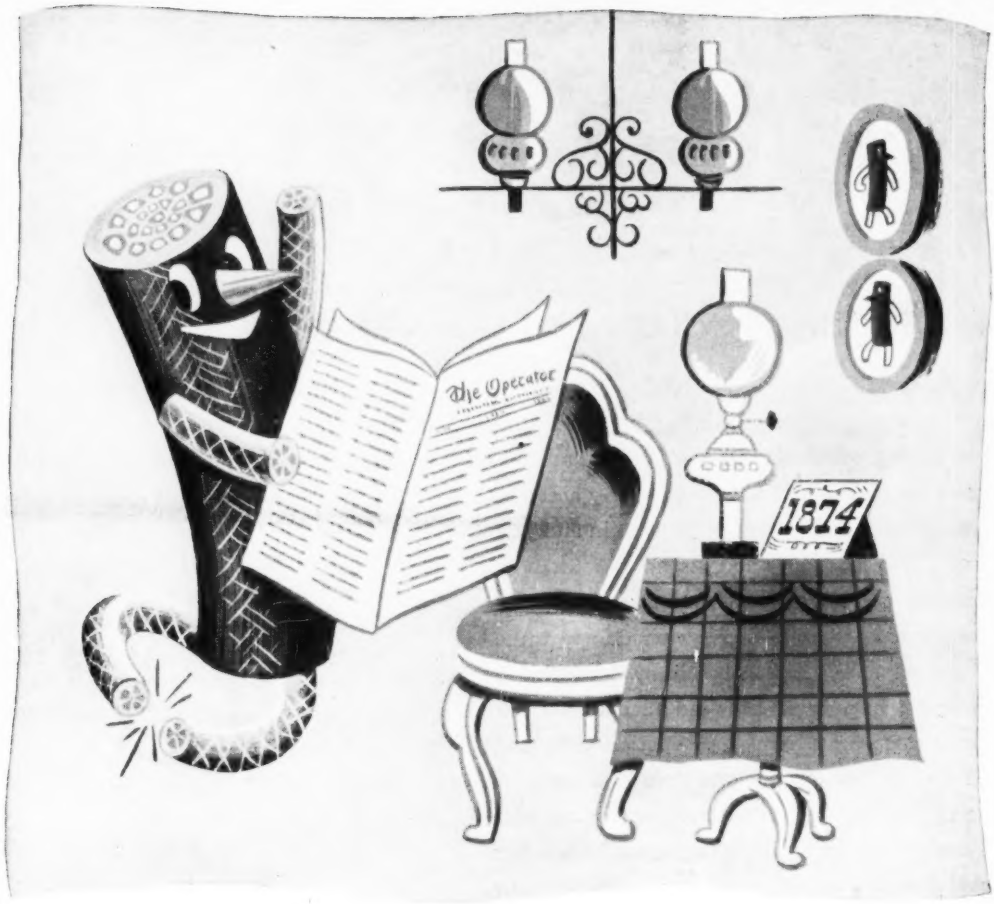


UNICLAMP CONNECTORS

W. N. MATTHEWS CORPORATION

3850 DELOR STREET ST. LOUIS 16, MO.

ENGINEERS and MANUFACTURERS SINCE 1899



"Just what the Electrical Industry needs..."

From Seymour Kerite's diary:

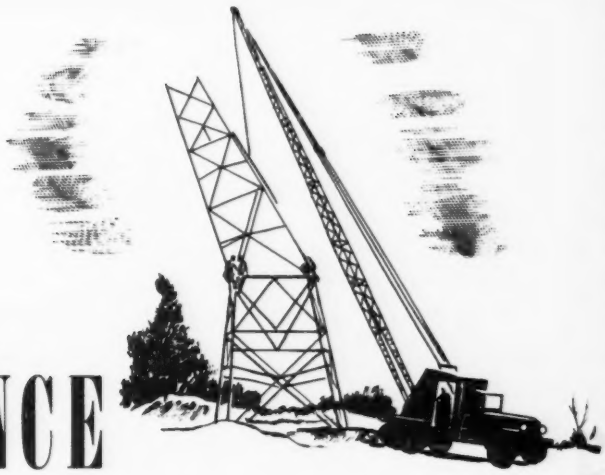
"**1874.** Looks like a good year. Telegraph industry growing fast. Glad I got in on the ground floor with Mr. Morse 14 years ago. New magazine appears today—'The Operator.' Good publication. Much needed. Should expand and grow with the electrical industry. Wonder how things will look 75 years from now?"

"**1949.** Just been looking at the 75th Anniversary issue of Electrical World. Remember when it started out as 'The Operator.' Great publication. Great job. Glad we've grown up together in the electrical power industry. Future looks good!"

The Kerite Company, 30 Church Street, New York 7, N. Y.

Kerite Insulation—Your Cable's Best Life Insurance

KERITE CABLE



MAINTENANCE AND METERING

LINE CONSTRUCTION METHODS

INSULATION TEST AND MAINTENANCE

POWER METERING

Much of what is embraced in the preceding technical sections dealt with equipments and their coordination to attain advantageous system results in a planned procedure. Next in sequence is the orderly installation of the facilities as economically and durably as possible. Then there is to be told the task of patrolling, inspecting, testing and repairing to keep the system working smoothly and effectively. Finally, there have been aggressive and unusually well coordinated efforts to improve the device which in many respects is the end factor of all utility efforts – the watthour meter which serves as the industry's cash register. In that article the primary author has had particularly authoritative collaboration in putting together a portrayal of the evolution of the watthour meter (along with the demand meter and the instrument transformers) to a commendable plane of accuracy, permanence and economy in administration.

PUSH OUT
AND FOLD

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Line Construction Methods

Aerial mapping, improved anchoring, mechanization of excavation and tower erection, modernized trucks, engineered layouts, better means for pole setting and material handling mark progress in construction procedures

PRIOR to the middle 1920's material available for starting a survey on which to base construction of a transmission line was limited to a topographical or post office map on which was indicated only the terminal points and general route of the line. This general route was selected by experienced construction men after "scouting" the terrritory to determine a route with the least obstructions. A trial survey, parts of which had to be redone many times, was necessary before suitable tangent line sections, with a minimum of angles, were established. As this survey progressed many inquiries were made by land owners as to the reason for the survey. Frequently the chief of the party was ordered off as a trespasser and it was necessary for him to spend considerable time securing permission to survey. The preliminary survey was followed by a permanent survey to mark the line suitably for construction. From this survey property line maps were prepared for right of way purchase. After securing, the right of way was cleared and towers staked out from a plan and profile prepared from the surveyor's notes.

Aerial Mapping

In some instances preparation of maps for transmission line construction was materially expedited by use of aerial photography. Refinements of aerial photography, developed later, permitted the preparation of fairly accurate maps of a "scouted" line. It permitted selecting a line location with a minimum of timber clearance. From aerial photographs a mosaic of the line was prepared. This mosaic was composed of standard size aerial photographs trimmed so the more accurate center sections of the photographs were matched and glued on heavy cardboard. From courthouse records the parcels of real estate and names of owners were secured and put on this mosaic in white ink. Copies of it were then made for the surveying crew and the right of way purchaser. Both crews started their work simultaneously, eliminating some of the troubles experienced with property owners when a survey was started before any right of way was purchased.

In many localities government aerial photographs could be purchased, as early as 1935, considerably cheaper than the cost of making a special aerial survey. These were satisfactory until they became obsolete because they did not show recently constructed buildings.

Plan and Profile Survey

It is now necessary in many cases to contract for a large majority of the rights of way on a tentative basis before an accurate survey is made. The procedure, however, is essentially the same, except that considerable time is saved by the use of jeeps to haul the surveyors and their instruments to the inaccessible places.

Locating towers for major transmission lines has always required the assistance of a plan and profile survey. The transmission towers are located by using a sag template of the conductor being used, marking the tower locations so as to get proper ground clearance when the conductors are in service. This procedure has not changed materially since 1925, but the accuracy of sag templates has improved with increasing knowledge concerning sags.

Transmission tower anchor holes were more frequently dug by hand in 1925, requiring possibly eight men and an average of two days to dig anchor holes

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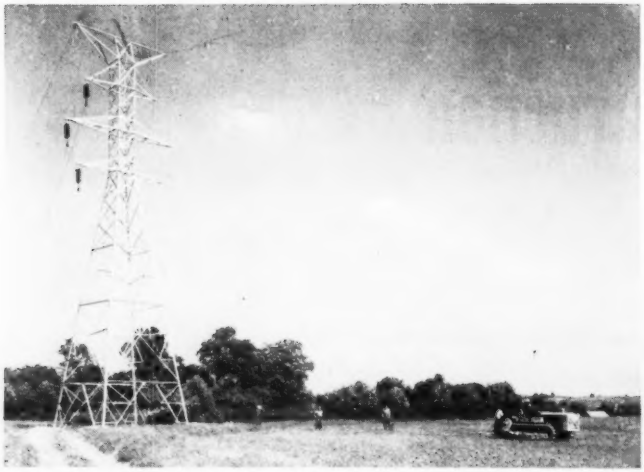


MODERN winch-equipped tractor (left) for sagging conductors. Truck-mounted lifting frame (right) for assembling towers

BACK HOE DIGGER used for excavating tower anchor holes

for one tower in fairly good country. If water were present, additional men operating hand pumps were required to unwater the holes to permit excavation. In rocky holes or frozen ground much more time was required and if blasting were required, drilling was mostly done by hand, some with power drills but generally requiring further manhours to complete. On many older tower lines sufficient engineering was not done in the field to secure adequate sidehill extensions for rough terrain locations. As a result towers meant for level terrain were used so that on steep hillsides the uphill anchor holes were often very deep. This required platforms in the holes at intervals so that dirt and rock could be lifted out. Often this dirt and rock was handled with a windlass and bucket mounted on a tripod over the hole. Where such procedures were necessary many men were required.

Diggers Introduced

This manpower required commensurate supervision for proper coordination. To expedite work and reduce labor and supervision manhours the clamshell digger was introduced to excavate anchor holes. However, it was only applicable to certain types of soil and could be handled only on fairly level terrain. It lacked mobility so that it required transportation by trailer and truck from one site to another. Although equipped with caterpillar treads, its speed was about four miles per day, making its movement slow and awkward. The use of a ditching machine to break through the ground around the periphery of the anchor hole speeded up the operation of the clamshell digger. Under favorable conditions the ditching machine could be used for the entire hole. One of the most striking reductions in excavation labor came about when effective field engineering allowed towers to be equipped with hillside extensions which markedly reduced excavation.

One type of modern excavation equipment is the back hoe digger, now used on many footing excavation jobs. It scoops dirt towards the machine, swinging it to one side as the digging arm rises. This machine, in favorable country, can dig anchor holes for two or more towers per day supplemented by two or three inches of spade excavation for grading. This machine is light in weight, travels speedily on caterpillar treads and is highly manuverable even on rather rugged terrain. It requires the assistance of the clamshell digger, however, when holes are wet, requires sheeting or requires foundation piles. For these cases the clamshell does the digging and drives the sheeting and piling. Sometimes the sheeting can be allowed to sink as the hole is dug. In certain localities the combination of the two digging machines along with a ditching machine represents the most efficient present-day practice. Beyond these, if conditions permit, a large diameter earth

auger can be used to secure top economy in anchor hole excavation.

The methods of erecting steel towers have not changed to any great extent from the time steel towers were first used for transmission lines, except that over the period of years improvements in efficiency and reduction in manhours to erect the towers have been accomplished by various combinations of hand erection, assembly of whole or part of towers on the ground and then erecting them by means of gin poles or truck mounted lifting frames especially designed for that purpose. In many cases setting templates used to be required for placing the anchors. These were both heavy and bulky and one or more were required for each type of tower and for each length of each type of tower. As many as eight setting templates might be required for a short line and since these were rather large it required horses to haul them on sleds or wagons between tower locations. The more modern method of setting anchors is to utilize the bottom tower section as a setting template. Consequently the erection of the first tower section by the anchor setting crew with a truck, tripod and surveying equipment is now done in much less time than was formerly required.

Mechanized Handling

Methods used in unloading, storing and handling steel have been improved and the use of mechanized equipment has speeded up the work of unloading steel and hauling material to tower locations. Specially designed trucks carry the steel for one complete tower. These trucks are built to make the selection of the individual pieces of the tower much easier. Shortages of parts can be determined from the overall material lists which summarize the pieces in each yard without the haphazard method of searching for any particular member in all the yards.

Construction records have been improved in the last twenty-five years by field engineers and inspectors so that a complete record is available when a project is finished. Now as the job progresses all information pertaining to unloading of material, foundation work, erecting towers and stringing wire is compiled and summarized from day to day. A summary sheet shows at what unloading points each tower member, reel of wire, or crate of insulators has been received. A similar record shows the exact location where each reel of wire is used, along with complete information covering sag and tension at each check span on the line.

Oxen and Mules Superseded

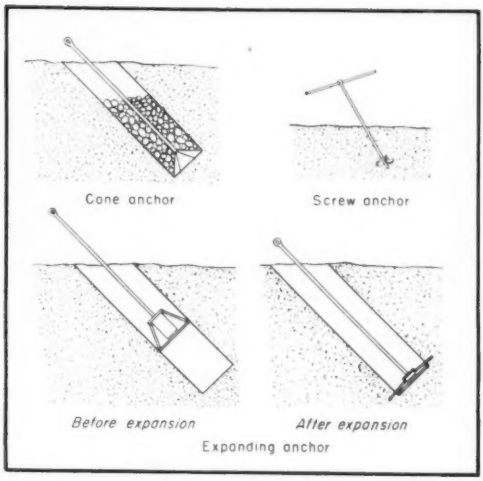
When stringing and sagging wire on a transmission line in the early days, most of the pulling was done without the aid of machinery. Farm animals, which were slow but much more reliable than any machinery available at that time, were utilized. It was often necessary to have a team trained to hold a sagged line so that it could be fastened in position. During the last few years the horses, mules and oxen have been replaced by powerful and much more reliable tractors and winches which provide the necessary motive power with much less supervisory manpower. More care is now taken to spotting of the wire reels of specified lengths to take advantage of natural temporary anchorages.

HYDRAULICALLY OPERATED lifting jacks easily remove heavy poles

MODERN DIGGER mounted on four-wheel drive truck

Walkie-Talkies

In 1925 hand signaling was universally used in stringing and sagging wires. This method was not only slow and difficult but required a man on at least every other tower. Later the number of men was reduced by use of hand telephone sets utilizing one of the conductors which was hung on insulators when strung. This provided material improvement in the stringing and sagging operation. Since the last world war, however, both of the above methods have now been advantageously replaced with space radio or walkie-talkie sets. This is probably the most important advance made for



SOME TYPES of patent anchors used today

this operation because it permits instant contact between the widely separated forces conducting the operation.

Pole Setting

Replacing or setting poles in the middle 1920's was a much slower job requiring more manpower than today. In many cases poles were set by hand methods which still must be used when the locations will not permit the use of a winch and derrick. The pole being replaced was used as a gin pole if it were strong enough and could be properly guyed. In some instances where a tall pole was installed at a new location, a smaller pole had to be set to be used as a gin pole for erecting the larger one.

Removing an old pole was usually accomplished by sawing it off at the ground. The stub was removed by hand using pole jacks. Frequently the stubs were left in the ground and when they rotted became a source of accidents. The practice of sawing off poles was sometimes warranted if the pole being removed was not good for use elsewhere and if the butt was removed. This method was also used to expedite the installation time and a good pole was often sacrificed or the remainder used as a shorter pole.

Pole Treatment

In some localities, particularly those of the Appalachian Mountain Range of Virginia and West Virginia, the chestnut pole was cut from timber in the locality in which it was to be used, a fact that materially reduced the price of the poles in use in that locality. In some localities farther west and north the northern white cedar pole cost less and could be secured easiest. Both of these poles were originally untreated and were eventually discontinued because of lack of supply and, because the stronger western red cedar and treated southern pine poles better fulfilled requirements.

Winch and Derrick

Because of increased distribution activities requiring longer and higher cost poles considerably more facilities were required when installing them, and by 1930 there was hardly an area that did not have at least one truck equipped with winch and derrick. It handled those jobs requiring heavy equipment and was used when installing or replacing large quantities of poles. With this truck a good size pole in good condition could be pulled from its hole without the use of heavy hand-operated jacks. However, the heavier and taller poles still had to be removed by jacks. Some jacks now hydraulically operated are much quicker than the old hand-operated jacks. The winch and derrick truck proved such a work expediter that by 1940 they were in general use and now no line construction gang of any size is without one.

Anchors Improved

At the turn of the quarter century anchors were usually buried logs or pieces of old pole salvaged for that purpose. To properly install such an anchor required digging a very large hole which usually meant the work of two or three men for a half day or more. The patent anchor was also used some, but construction men were skeptical of its holding power and consequently it was used only on the very light strains where it was reasonably sure not to give trouble. Unfortunately, when the patent anchor did give trouble it was usually because it was not correctly applied or installed because of lack of preliminary engineering.

Over the past 25 years the relative use of log anchors and patent anchors has been reversed, and the log anchor is used only in very special cases. This transition resulted from the simplicity of intallation of the patent anchor, it requiring only a hole 6 to 8 ft deep and 8 to 10 in. in diameter. This can be dug by a post hole or special anchor hole digger. When a mechanical digger is on the job there is usually available a blade for digging anchor holes. Patent anchors are now available which have sufficient holding power in some soils to completely eliminate need for leg anchors.

Guy-wire Installation

Installing guy wires in the early days was a real major operation, requiring the use of block and tackle and tools to hold on to the guy strand. Usually three or four men were required to install a guy wire in order that sufficient strain could be put in the guy strand so that when the conductors were sagged in the pole would not be deflected. This slow process of installing guy wires has been materially expedited by the use of a ratchet tension device instead of the several men with block and tackle, and now only a few minutes are required for installing the average guy. The use of bolted guy attachments at the pole end of a guy strand now permits the wire to be made up entirely on the ground, hung in place and then pulled up at the anchor end.

Line Trucks

Line trucks have changed materially over the past

twenty-five years. Just after World War I the usual line truck was a chassis and cab on which was mounted a stake body made of wood. The body had upright bars on the sides which were used to support a tarpaulin along with the usual required rope blocks. The tools were stored in a wooden tool box in the body behind the cab and sometimes the above mentioned tarpaulin was present in order to protect the tool box and rope blocks. When transporting linemen to and from jobs they sat on the tool box or any convenient place in the truck body, protected from inclement weather by the tarpaulin. In those days most trucks had two-wheel mechanical brakes and the larger ones had solid rubber tires. The lighter ones had single high pressure tires. The gradual extension of distribution activities required more space on the truck for tools and equipment so wooden tool boxes were suspended from the sides of the stake body to form the fenders of the rear wheels. These tool boxes permitted the elimination of the tool box in the body and allowed more room for carrying material to the various jobs. As previously stated, by 1930 practically every operating area had a line truck equipped with a winch and derrick for setting and pulling poles. Trucks equipped with these devices were used on the major construction jobs where the winch and derrick would be used most. Greater distribution activities required more such devices in order that the expanding use of electric energy could be properly served. About 1935 the wood body truck was replaced by more durable steel. Steel bodies usually outlast their original chassis while the old wood ones would have to be replaced before the chassis was worn out. Since about 1940 practically all line crews doing distribution line work were using trucks equipped with the winch and derrick. The modern medium-sized line trucks are now equipped with a seven-man cab, streamlined in appearance and with special compartments designed to carry the many tools required to do the distribution work.

Earth Augers

When a distribution line was to be constructed in rough or hilly country it was usually a major operation requiring considerable manpower for the clearing of right of way, digging holes, erecting poles and stringing wire. Most of these duties were done by hand without the aid of machinery. The material could only be hauled part of the way by truck and then teams of horses or mules pulling sleds finished the job. Often the last one or two hundred feet required manpower because the terrain was too rough for teams to operate in. Some of these rough country construction jobs must still be done that way except that lately there have been developments to speed up this operation. Right of way is now cleared by power saws, and underbrush is killed by chemicals. Poles and materials are hauled from delivery points to the inaccessible locations by caterpillar tractors. The same tractors now do the wire stringing labor formerly supplied by animal teams. Where the use of an earth auger is impractical dirt holes are now dug by the aid of dynamite. The hole is started at the correct diameter and dug about two feet deep and then a digging bar is "churned" down about two or three feet more. Into this hole a half stick of 40% dynamite is inserted and detonated. Thus a pole is completed in about ½ to ¾ of an hour at a great saving in time.

Live-Line Maintenance

Distribution hot line work and a scheduled safety program tie in very closely. In the mid-twenties there were not many safety devices in use. There was some hot line work to do and some men who considered themselves rugged enough to do it. Most of the 2,300-v circuits, and on dry days 6,900-v circuits, were worked with leather gloves. In those days rubber goods and protective devices were not used too extensively on a voluntary basis. Some linemen considered these devices bothersome and awkward and used them as little as possible. Obviously there were many unnecessary accidents. In those days the lower voltage distribution circuits were mostly 2,300-v delta and with the coming of higher voltages, the first step of which was to convert to 4 kv Y, it was necessary to be more careful in order to provide safe working conditions. The growth of the use of electrical energy and the expansion of the distribution system required the lines be left energized. Today, continuity of service is most important and any premeditated outage must take place at prearranged times. To avoid outages much more distribution hot line work is required. Distribution changes of today require such safety devices as rubber gloves, hose, blankets, insulator hoods, and various other protective devices so that regular distribution work may proceed without a service outage. Fortunately, the manufacturers of such tools have kept pace with the requirements and have made available such safety articles as 20,000-v thin wall gloves, rubber protectors for pole climbers, or hooks, high voltage flexible jumpers and safety platforms. For the higher distribution voltages hot sticks are now in general use for such operations as changing insulators at tangent or deadend poles and doing various other distribution jobs that used to require a line outage.

Future Prospects

Just what the future will bring in transmission and distribution construction practices may be partially determined by the trend of past changes. In practically every case improvements in construction practices have been the result of the development of new construction methods and the use and development of new tools and the more efficient use of existing ones. Careful thought in using available equipment to the best advantage will prove considerably less expensive and will offer many opportunities to expedite work. It is true that present-day construction usually requires considerably more mechanical aids because of the many complex operations involved. However, the purchase of new tools and machinery should always be on the basis of sufficient use to secure economy. The diligent application of the above principles will further improve construction practices, reduce construction costs and thus help to keep the cost of electrical energy at a minimum.

Insulation Test and Maintenance

Apparatus and line reliability progressively enhanced by refinement of test and maintenance methods for transformers, bushings, breakers, arresters, line insulators, insulating oil, cables and potheads. Non-destructive field tests advantageous

TRANSMISSION of larger and larger blocks of power led to outdoor installations, longer lines and increased short-circuit capacities exposing insulation more and more to the elements and to greater electrical and mechanical stresses. Furthermore, the apparatus designer had not as yet fully recognized the importance of the mechanical details required to protect insulation from destructive influences in service. Too frequent equipment failures and the greater demand for service continuity focused more attention on design details, preventive maintenance and routine insulation testing.

Spurred on by these needs the dielectric properties of insulation began to be more generally known and understood. The use of some of these properties for the non-destructive evaluation of the condition of electrical insulation began to develop. The study of lightning phenomena was advanced by the development of the surge generator and cathode ray oscillograph. By 1930 surge generators for over a million volts were in use and much experimental work on insulation was underway.

Early Insulation Testing

Prior to 1924, the testing of electrical rotating equipment in the factory and the field to determine the condition and predict the service reliability of the insulation was confined to dielectric strength tests using direct current or alternating current at commercial frequencies. Insulation resistance testing was used to attempt to evaluate the condition of the insulation but its effectiveness was somewhat limited due to the general lack of understanding of its components and their variations.

In the case of power transformers and induction voltage regulators, the dielectric tests of the solid and liquid insulants were limited to low frequency dielectric tests and induced voltage tests. The low frequency test was considered an adequate test of the major insulation with respect to ground. The induced voltage test was usually made at a higher than normal frequency for the purpose of developing a suitable voltage between turns and between coils in a winding in order that the interposed insulation be adequately tested.

As operating voltages were increased, interest developed in graded insulation for power transformers because of the economies involved. The use of graded insulation necessitated a suitable dielectric test procedure. When the major insulation was graded, the low frequency dielectric test to ground could only be made at the test level of the neutral terminal. The line terminal could not be tested at its appropriate low frequency test level. Thus, it became necessary to depend upon the induced voltage test to fulfill the multiple purpose of testing between turns and coils and furnish a suitable test to ground for the line end of the winding. The low voltage d-c test was used in the factory to check transformer insulation dryness and in the field for general service condition (Fig 1).

Testing of oil circuit breaker insulation was confined (1924-1930) principally to the application of high voltage a-c at commercial frequencies. The low voltage d-c test was used in the field mainly in conjunction with maintenance inspections. The electrolytic and oxide film lightning arresters presented relatively few problems from an insulation test point of view. Factory tests were made at high potential but very few, if any, field tests were made.

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Cable Testing

The rapid load growth in urban areas naturally required the expansion of underground cable systems and introduced new problems in the design of high voltage cables. Experimental testing of dielectric materials by use of insulation resistance, dielectric loss and high potential-time tests resulted in the development of lead-covered solid-type cable for 66-kv service about 1924. The low-voltage d-c test was used mainly in connection with maintenance of potheads and splices of older designs. As improvements in pothead design and splicing technique progressed, and as underground systems extended over wider areas, this type of test became less useful from an economic point of view. Also, as the length of cable lines increased, the charging current required in high potential a-c testing made it necessary to install relatively large and expensive test transformers. This encouraged the development of high-voltage d-c testing (Kenotron) and it was soon discovered that the current-time curve was an excellent criteria for determining the condition of the cable insulation. The solid cable factory testing techniques were transferred with slight variations to oil filled cable development in this period.

Insulator Tests

Factory testing of insulators, both pin and disc type consisted (1924-1930) mainly of high potential flashover and high potential-time tests using alternating current at commercial frequencies. High-frequency factory tests were also made during course of assembly. The failure rate of insulators in service prompted the development of a field test that could be adapted to "live line" conditions. This was accomplished by a non-insulated telephonic method whereby the variation in the leakage current gave an audible indication of the condition of the insulator. The use of this method was limited in that direct contact could not be made to the insulator. A second method known as the short circuit (buzz stick) test depends upon the voltage stresses as distributed over the various shells. The device is applied directly to an insulator, short circuiting a shell (or disc) and the length or strength of the arc is noted when one contact is moved to break the short circuit.

The above methods however, were not too accurate and introduced a safety hazard to personnel. Also, insulators continued to fail. This brought about the development of an insulated telephonic safety tester which is dependent upon the voltage stresses as distributed over the various shells of a pin-type insulator or units of a suspension string and produces an audible indication by use of an air gap in the circuit. The use of this device successfully weeded out defective insulators and the principles involved contributed to new and improved insulator design.

Oil and Bushings

Increased use of insulating oil for transformers, circuit breakers, cables, etc. necessitated investigation of test methods in this field. The main dielectric type of test was dielectric strength or high potential breakdown as an indicator of free moisture. This was supplemented by laboratory tests for acidity, pour point, steam emulsification number, color, etc. The danger of moisture in oil was recognized but the method of determination was limited to simple tests such as the hot nichrome wire.

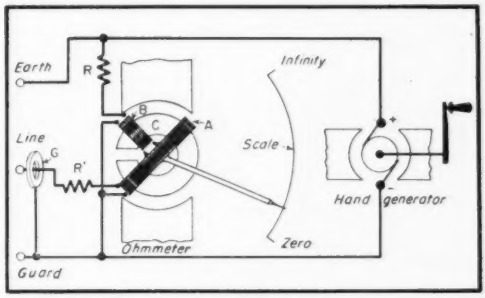

FIG 1—SIMPLIFIED DIAGRAM of Megger Insulation Resistance Tester (Courtesy James G. Biddle Co)

The increasing number of high-voltage bushing failures in transformers and oil circuit breakers during this period created another problem. The only non-destructive dielectric tests available were low-voltage direct current insulation tests and the application of line insulator testers to measure the voltage distribution over the porcelain rain shed. These tests were inadequate as indicated by continuing service interruptions due to bushing failures. An apparatus was then developed for measuring the charging current of a bushing at operating line voltage by isolating on an insulating support a current instrument arranged for connection in series between the terminal of the bushing and the live line normally leading to it. This test did not reveal certain types of defects in insulation and service interruptions continued to occur. Finally in 1929 a non-destructive, 60-cycle, voltampere-watt method was developed and successfully applied for measuring dielectric loss and power factor of bushing insulation (Fig 2). This method, where used, has definitely reduced bushing failures to a minimum.

Preventive Objectives

Dielectric strength tests using direct current or alternating current at commercial frequencies were still (1930-1940) the primary methods for evaluating the fitness and service reliability of the insulation in the windings of electrical rotating equipment. In addition, however, dielectric strength tests using impulse voltages were used in the factory for turn-to-turn testing. Use of the low-voltage d-c insulation resistance test was continued. Increased desire in the field for non-destructive evaluation of the insulation aroused interest in dielectric absorption (time-resistance) tests on generator windings.

The mystery of variable resistance readings gave way to the discovery that real factors were involved such as: Inherent moisture, time of application of voltage, previous storage of charge, test voltage magnitude, temperature, class of insulation, end-winding treatment,

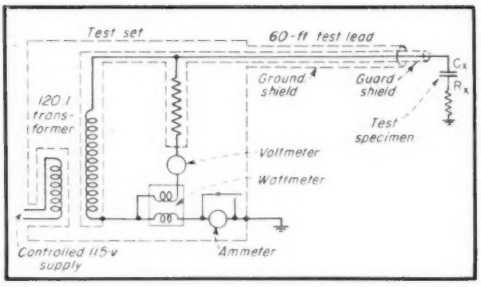

FIG 2—SIMPLIFIED DIAGRAM of Doble I-30 test set for measuring dielectric loss and power factor

and dirt accumulation. It was essential to make evaluations of resistance on generators having no moisture deposited from the air so the standard practice was established of taking readings on a warm machine following a load period. Experimental work on dielectric loss tests was also started in this period.

Impulse Testing

In applying the information previously obtained by the experimental work performed in the use of impulse voltage testing, the previous practice of adding more insulation to transformer windings in an effort to prevent field failure due to lightning voltages became unnecessary. The first impulse tests applied on large commercial power transformers were made in 1931. This test is similar to the chopped wave tests given to present day power transformers to check designs and control the quality of materials and workmanship. Impulse testing techniques have undergone a number of changes, stimulated primarily by the experiences accumulated from conducting such tests.

Field Dielectric Tests

The use of the dielectric loss and power factor method was first applied in the field on power and instrument transformers in 1936. This type of dielectric test proved successful in locating defective bushings, windings, and oil in transformers of all sizes, makes and voltages. A large number of factory power factor tests on distribution, instrument, and power transformers were also made during this period.

The factory testing of circuit breaker insulation continued with high-voltage a-c at commercial frequencies and the use of impluse voltage tests for design development. The field testing of this equipment by the dielectric loss and power factor method became routine procedure for many power companies. Defective bushings, lift rods, braces, tank liners and oil were readily determined.

Arresters and Cables

A radical change of design occurred in the field of station type lightning arresters. The composition blocks and gaps were enclosed in porcelain housings and introduced moisture proofing problems. The dielectric loss and power factor test was applied to this problem in the field. This test will not show changes in surge characteristics of the arrester but it does indicate the type of deterioration that frequently causes failure under 60-cycle conditions.

Factory tests on cable during this decade were supplemented by the development of the ionization factor (change in power factor with increase in test potential) for determining the condition of the insulation. Experimental work with oil pipe cable lines started in 1932. Here again, the solid cable factory testing techniques were transferred to the development of this design with only slight variations. The development of the hot-collar test used in conjunction with the insulation power factor test equipment made possible the testing of cable potheads without disturbing the cable sheath.

Bus Insulators

In testing bus insulators in switch yards it was found that asymmetrical electrostatic fields interfered with the results obtain with testers operating on the voltage-distribution principle. Here again the dielectric loss and power factor method was applied. Due to the increased interest in "live line" insulator testing, a new device was developed in 1939 which by use of a micro-ammeter produces a scale deflection in measuring relative values of the potential difference between two test prongs or the charging current to ground by a one prong method.

Until 1935 the accepted dielectric test for insulating oil was still the dielectric breakdown test at high voltage. Experimental work on dielectric loss in oils brought about the adaptation of the a-c dielectric loss and power factor method as one of the criteria for the condition of the oil. Laboratory experimental work was started in the field of inter-facial tension testing and the measurement of the absolute water content in used oils.

Rotating Equipment

The test methods previously described for rotating equipment have been supplemented by additional developments. In an effort, to find an improved means for locating faults between turns in coils and windings, as well as between windings and ground, a surge comparison tester was devised. This applies surge voltages alternately in reverse directions through the winding and the results are observed on a cathode ray oscilloscope. Another variation of this method consists of applying undirectional surges through a winding and comparing the magnetic flux produced by parts of the winding as observed by two pickup coils.

During 1946 a slot discharge tester was developed for detecting and locating capacity discharges on high voltage machines such as may occur between the semi-conducting surface of the coils and the punchings when the semi-conducting surface is unsatisfactorily grounded. In order to solve the problem of probable insulation level on large coils in high voltage machine windings without testing each coil, statistical analysis methods and probability theory have been applied with enlightening results. Dielectric loss tests

and corona ionization tests on rotating equipment have not, as yet, proved effective in the evaluation of the condition of insulation on the windings.

Impulse testing techniques as applied to transformers were improved during the war period. Comparisons of the neutral current wave form as well as the line end applied voltage wave form obtained with the reduced full wave and with the full magnitude full wave are reliable indicators of failure. A short time (one minute) dielectric absorption test for field testing of transformer insulation was introduced as a supplement to the dielectric loss test.

The testing of circuit breakers, lightning arresters, insulators, and oil during this period has been largely confined to the same methods as previously described. Variations of method and improved standards, however, have been incorporated as the result of previous experience gained.

Insulation Resistance

The improvement in cable design has brought about certain changes in test application. Insulation resistance testing became of less importance until today it is no longer required in specifications. The time-current curve obtained by d-c test is not very significant on cable made with the improved impregnating oils and the routine high voltage d-c test has steadily lost favor. It is still used however for acceptance testing, proof testing following repairs, and for fault location. The development of gas pipe cable lines in 1942 introduced another problem. The testing of this type of cable is still in a somewhat controversial stage.

In an effort to improve the finished product, the last few years have witnessed the standardization of "Quality Control" tests by the various manufacturers. The improvement in insulation test techniques have been advanced by the cooperative efforts of manufacturer and utility personnel. The work of the national organizations such as AIEE, EEI, ASA, NEMA, AEIC, ASTM and others have been largely responsible for the crystallization of opinions and adoption of present standards for test values and test methods. The details regarding the various types of tests mentioned in this paper may be reviewed by reference to the literature of the time.

Problems for Future

There are many problems remaining for future study. Further coordination and evaluation of information on existing non-destructive test methods to develop a more positive means of gauging the condition of insulation and predicting service fitness and reliability is paramount. The corollary of this would be further standardization of non-destructive tests on insulation to enable coordination and evaluation of data. The trend toward higher transmission voltages, larger capacity generators, air and air blast circuit breakers, dry-type transformers, etc will unquestionably present new problems both in the factory and the field. The studies on corona and insulating oil for apparatus and cables must go on. Investigation of the possible application of dielectric loss tests to factory control of insulator manufacture may have merit. Truly, the next quarter century does not promise any let down of present effort in the field of dielectric testing.

Twenty-five years ago the electrical insulation maintenance program was largely a mechanical cleaning procedure which was dictated primarily by experience. Electrical tests were usually a secondary part of the program. There was a definite lack of wide acceptance of any given maintenance practice. Due to economic pressure and the ever present desire to insure service continuity, the general adoption of "preventive maintenance" programs in the early thirties provided the stimulus required to place field maintenance of insulation on a firm basis. The interest in this subject has progressed steadily up to the present time.

Today, the use of non-destructive electrical tests in the field to determine the immediate condition of high voltage insulation is a definite part of any maintenance program. The effectiveness of modern electrical maintenance testing is largely due to three major factors:

(A) The development of field test methods previously mentioned.

(B) The cooperation of a large number of power companies in a group activity to apply the tests and develop operating techniques and establish acceptable base lines from analysis of pooled data.

(C) Interest and cooperation of the electrical equipment manufacturers.

Preventive Maintenance

Since the economics involved in establishing a "preventive maintenance" program must be governed by the results obtained, it is only necessary to consult the literature describing the increased equipment failure rates during the war years when in some cases, well established maintenance programs were severely curtailed or eliminated due to inability to take equipment out of service and/or labor shortage.

In line with the development of dielectric test techniques, the more commonly used electrical maintenance tests for high-voltage rotating equipment insulation are: The low-voltage d-c resistance test, the dielectric absorption test, the power factor test, ionization and slot discharge tests and the high potential test. The practice of removing dirt and oil accumulation from the windings by blowing or wiping, and in some cases the application of insulating varnish, has not changed through the years. The use of air washers, various types of air filters and the introduction of the hydrogen-cooled units have been factors in extending maintenance programs.

Dry-out Procedure

Where moisture presents a problem, it may be removed by a simple dry-out procedure of rotating the unit for a period of time at no voltage, depending on windage to remove the greater part of the moisture as indicated by frequent low voltage d-c resistance tests. The *gradual* loading of the generator would then be accomplished on a temperature rise basis. If the moisture condition is severe such as occasioned by floods, etc, it will be necessary to introduce current in

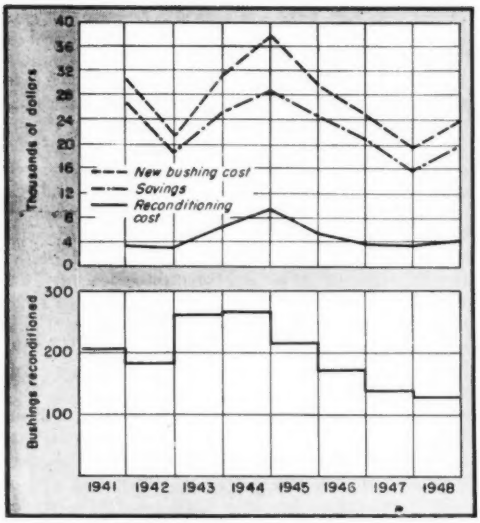

FIG 3—RECONDITIONING 1563 transformer and circuit breaker bushings for approximately 18% of cost of new bushings

the windings and also apply heat from the outside.

Further development, application and standardization of the present dielectric tests as applied in the field to rotating equipment insulation should establish a more firm criteria for exact determination of insulation replacement.

Apparatus Reconditioning

The maintenance technique applied to high voltage power and instrument transformers progressed from the early stages of occasional visual inspection, low voltage d-c resistance tests, and oil tests to periodic scheduling of these tests. The dielectric loss and power factor tests stimulated further investigation of transformer insulation which resulted in major reconditioning programs. Development of shop techniques introduced many features which added to the economic picture. The drying of windings progressed from the short circuit method in oil to circulation of warm air with the winding out of oil.

Vacuum oven drying led to the application of short circuit winding and partial vacuum in its own tank. During the war years when spare transformers were scarce, a new method of drying windings was developed by providing an air space above the oil and circulating the air (or nitrogen) through silica-gel containers while the transformer remained in service. This method was applied to free breathing, conservator, and gas sealed transformers.

Shop Overhaul

Due to the large number of defective transformer and circuit breaker bushings that were located by use of the dielectric loss and power factor test, it was found expedient by many companies to set up shop facilities to make necessary repairs. This work extended the service life of thousands of bushings at a nominal cost (Fig 3) and through cooperation with the manufacturer, resulted in many major design changes.

Field maintenance on circuit breaker insulation such as lift rods and braces, tank liners, arc control devices, etc kept pace with the development of dielectric test technique.

Maintenance of underground cable systems is largely a problem of replacing deteriorated sections of cable or splices as indicated by various dielectric tests. High-voltage potheads may be classed in the same category as bushings. The desire for quick restoration of service after a cable failure has introduced the problem of fault location and many varied methods have been developed.

Oil Purification

During the past twenty-five years the subject of insulating oil purification has received increasing attention due to the resultant effect on efficient operation. During the early part of the period, moisture and sediment were removed from deteriorated oil by use of the centrifuge and blotter press. It was recognized, however, that these methods did not remove the deterioration products which were in the process of formation and were not, as yet, thrown down as sludge. Interest then centered on the use of fuller's earth as it was established that dissolved oxidation products and other objectionable contaminants could be removed by a filtration process. The use of this method restored acidity and color to approximately the level of new oil. The need for special treatment of cable oil resulted in the development of degasifying equipment. In 1932 the use of activated alumina was developed as an adsorbent for the filtration process.

In order to prevent the entrance of moisture into free breathing and conservator type transformers and to eliminate the unsatisfactory calcium chloride breathers, activated alumina, silica-gel and other adsorbents gradually came into use. There was also a need for some method to economically maintain transformer oil in good condition in new transformers and to protect the investment made in reconditioning old transformers. This resulted in the development of the thermo-syphon by-pass filter which operates on a temperature difference principle with the transformer in service. In line with the economy involved in reclaiming deteriorated oil, both portable and stationary equipment has been developed using a combined method of adsorbent filtration for removal of solids and soluble oxidation products, and vacuum vaporization for removal of moisture, dissolved gases, and other volatile contaminants.

The trend toward further system expansion increases the general maintenance problem. However, the development of new apparatus by the manufacturer, and the application of modern maintenance test and reconditioning methods to existing equipment should result in spreading present maintenance schedules without sacrificing service reliability. The proof of this depends on how well the present job is being done.

Power Metering

Watthour meters first improved in range and accuracy, later in uniformity, mounting methods and surge-proof characteristics. Corresponding advances in demand measurement techniques and in instrument transformers

MUCH HAD OCCURRED in the evolution of metering by the mid-twenties but it was at this time that a new chapter of advancement began. The rapid growth of electric utilities had assured an increasing demand for meters and with this expansion came the need for rugged, dependable, mass-produced meters which would keep both initial expense and maintenance costs low.

The inventive spirit and enterprise which marked the earlier years of metering development left a remarkable record of achievement and there was reason to assume that the heritage established by the founders of the art of metering would be extended by increased technical knowledge, improved manufacturing processes, and new applications of materials.

Accuracy Progressively Improved

Meters available in the early twenties were fulfilling the immediate needs of the electric industry for instruments which would provide an appropriate means for measuring electricity. Meters at that time were capable of maintaining acceptable accuracy, construction features had been simplified, and size and weight reduced. Had they not been so satisfactory it is doubtful if so many would still be in service today.

In spite of the commendable characteristics of these earlier meters, changing conditions and the pursuit of perfection focused attention on challenging improvement possibilities. More significance was being attached to certain limitations of existing meters. There was concern over the inability of meters to satisfactorily register increasingly prevalent overloads; accuracy variations caused by temperature changes; bearing and lubrication difficulties; and installation complexities due to the variety of external designs.

The period of concern over these shortcomings was brief, for from fertile technical minds came a series of ingenious and practical solutions to the problems.

Overload Range Extended

A most significant development was the progressive extension of the overload range of meters to over 400% of rated capacity with little sacrifice in accuracy. With the ever increasing applications of electricity, electric utilities were confronted with the need for meters which would function properly over the wide range from the few watts required by electric clocks and bell-ringing transformers to the aggregate wattages of heat-developing appliances such as irons, toasters, waterheaters and ranges. To avoid the loss in registration which occurred when meters were loaded beyond their rated capacity it was necessary to overcome the characteristic of meters to produce a retarding magnetic force which increased at a more rapid rate than the magnetic driving torque.

This was ingeniously accomplished by two methods: 1. Redesigning meters to permit lower normal disk speeds so this counter force would be minimized and 2. forms of compensation which permit an increasing proportion of the magnetic driving force to act upon the disk at overloads and thus overcome the excessive retarding force which develops.

This improvement in meter performance coupled with an increased current capacity reduced the required number of meter sizes and meter stocks.

Temperature Compensation

Another disturbing characteristic of meters was the change in accuracy occasioned by variations in ambient temperatures. This was not a critical matter and was relatively unimportant if meters were installed at locations free from extreme temperature changes. However, it definitely created a deterrent to a full realization of benefits available from the practice of installing meters outdoors.

Considerable research was necessary to determine

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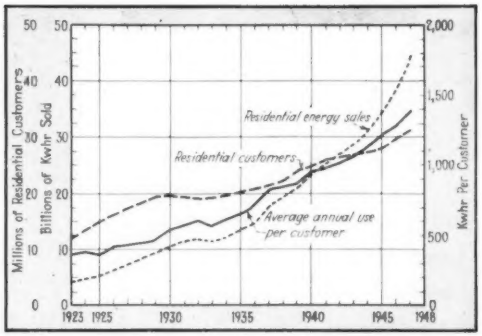

Millions of Residential Customers
Billions of Kwhr Sold
Kwhr Per Customer
Residential energy sales
Residential customers
Average annual use per customer
1923 1925 1930 1935 1940 1945 1948

FIG 1—GROWTH of residential customers, energy sales and average annual use per customer

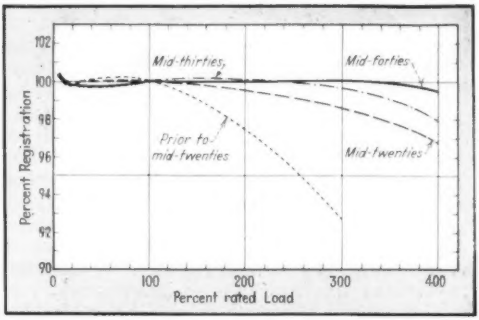


FIG 2—COMPOSITE accuracy performance curves of single-phase watthour meters discloses progress in three decades

that two general groups of factors cause temperature to affect meter accuracy. A principal example in each group is: 1. The characteristic of permanent magnets to weaken as temperature rises and 2. a variation of the phase displacement of potential coil flux with temperature changes. Complete temperature compensation of meters was accomplished by the adroit application of means for counteracting these effects. Temperature was thus eliminated as a factor in determining the location of meters.

Bearings

Because watthour meters in service are expected to function for years without attention, exacting demands are made on the bearing materials and lubricants used. The principal bearings of a meter are those which support the vertical shaft to which the disk is connected. These bearings have received constant attention from manufacturers as experience has demonstrated that failure of meters to register properly is caused principally by the factor of increasing friction which develops if the bearing conditions deteriorate.

The lower bearing supports the weight of the meter disk and shaft, and in the early twenties the most prevalent form of lower bearing was a steel pivot containing a sapphire jewel cup containing an oil lubricant.

Another form of bearing in use was a ball bearing placed between two cupped sapphires. This bearing required no lubricant and has been increasingly preferred. It is now widely used in the production of modern meters.

An innovation in bearing design has been introduced by the recent appearance of a meter which magnetically suspends the disk and shaft and thus nullifies part of the function of a lower bearing. This development represents a revival of a long recognized possibility which has awaited advanced engineering talent and improved materials to make a practical application possible. It is too early to assay the influence this development will have on the design of all meters.

The cumulative effect of improvements made in meter bearings has been a substantial reduction in the incidence of meter inaccuracy due to friction. The elimination of friction has been a significant factor in the trend to lengthened periodic-test intervals.

Permanent Magnets

As electric utilities expanded into rural areas, attention was focused on the susceptibility of meters to being rendered inaccurate by current surges caused by lightning which were not as readily dissipated as in urban areas. These surges passing in proximity to meters were frequently of sufficient magnitude to cause a demagnetization of the permanent magnets. The wiring arrangement of certain modern-type installations tended to emphasize this effect. This obstacle to dependable meter performance was overcome by the development of surge-resisting magnets. It was found that two methods were feasible; either magnets could be made from Alnico which has a high resistance to demagnetization or the existing types of magnets could be shielded with a heavy coating of copper. Alnico, which is unique because of its very great coercive force provided the added advantage of a considerable reduction in the size and weight of magnets.

Terminals and Glass Covers

Until the mid-twenties, manufacturers had pursued individual paths in respect to the external design of meters. The only semblance of uniformity was a general adoption of the bottom-connected type of meter and a trend toward meters of comparable size. As long as electric utilities connected meters on open wiring, dissimilarity was of little concern. However, the advent of more appropriate enclosed-type meter-connection facilities, introduced the need for meter-terminal standardization to prevent an unwarranted variety of such facilities. The manufacturers responded to this need by adopting standardized meter-terminal chambers. This permitted economy and simplification of installation facilities and was the forerunner of highly significant standardization activities.

Universal change to glass meter covers which could be locked in place eliminated the need for protruding studs and wingnuts for retention of the covers. The glass cover not only deters tampering but also improves

the appearance of meters and simplifies maintenance.

The Socket-Type or Type "S" Meter

Shortly after meter-terminal standardization had been attained, considerable interest developed in a new and different meter base and terminal design known as the detachable meter. Instead of being located at the bottom of the meter the meter terminals consisted of projecting switchblade lugs mounted on the back of the meter which could be plugged into switch jaws mounted in a receptacle fitting called a socket. Subsequently, this type of meter became known as the socket-type or type "S" meter and has enjoyed wide acceptance.

The Type "A" Meter

Concurrent with the development of the socket-type meter, standardized dimensions of bases, glass covers, and terminal chambers for all bottom-connected meters were established.

This was an outstanding example of the exceptional cooperation which has often been exhibited by the meter manufacturers in meeting the practical needs and expressed wants of the electric utilities. The standardized bottom-connected type meter is now designated as the type "A" meter and affords the advantages of permitting universal connection facilities. The type "A" meter also has terminals sufficiently similar to preceding types of meters to permit the replacement of meters on existing installation facilities.

Bases and Terminal Blocks

Another interesting improvement incorporated in type "A" meters is the use of die-cast aluminum alloy bases and frames which reduces weight and makes meters more resistant to corrosion as well as tampering.

The terminal chamber of bottom-connected meters is such that an insulating material is needed to support and isolate the current-carrying conductors. Various methods had been used for providing this insulation in earlier meters but for type "A" meters with standardized terminal chambers it became feasible to use pre-molded terminal blocks of insulating material which facilitate assembly and are readily replaced. To acquire a material which could be molded to the required intricate pattern and still possess ample strength and have adequate dielectric properties has necessitated considerable research into the applicability of various materials.

In addition to improved terminal-chamber insulation, equally significant improvements for other insulation requirements within meters have been made and have contributed to a reduction in meter failures attributable to dielectrics.

Meter and Time-Switch Combination

A particularly interesting adaptation of meters to specific needs of electric utilities was the development of watthour meters incorporating a time-switch which can be used to both meter and control the supply of electricity. Many utilities are using these meters in connection with off-peak water-heating service.

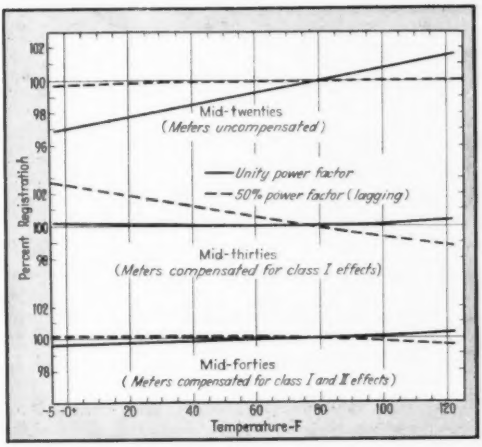


FIG 3—ACCURACY PERFORMANCE CURVES at rated load without and with compensation for temperature errors

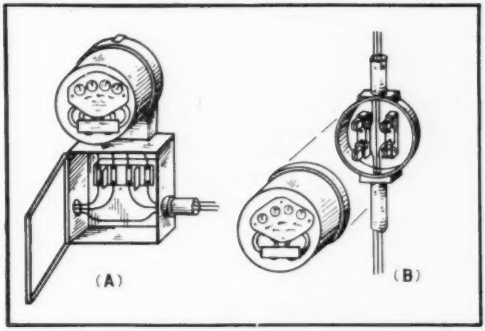


FIG 4—TYPICAL METER INSTALLATIONS: (A) A-base, for indoor use; (B) socket, for outdoor installation

Convertible 2 or 3-Wire Meter

With meters compensated to meet overloads there remained another metering problem occasioned by the increasing usage of electricity. Two-wire, 120-v service had been widely used as the normal supply to a majority of customers, particularly residential. Larger loads and the use of 240-v appliances necessitated a switch to the general adoption of three-wire, 240-v service. Because meters were not designed to accommodate the two ranges of voltages, a 120-v meter installed on a two-wire service which was subsequently changed to three-wire would have to be replaced. If the volume of such replaced 120-v meters exceeded the available opportunities for relocation there arose the problem of premature obsolescence of these meters. To avoid this possibility, combination two-wire and three-wire meters were made available which with minor changes can be applied to either type of service.

The growth in wye-network systems emphasized the need for less costly and smaller multi-element meters.

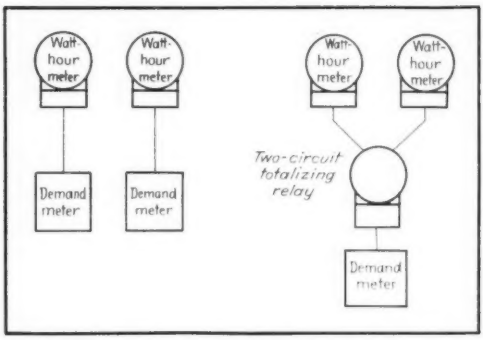


FIG 5—METHODS of obtaining totalized demand

In general, multi-element meters have consisted of either two or three physically separated single-phase meter elements, including disks, but driving a common shaft and register. This construction resulted in comparatively large, heavy, and costly meters.

However, through such improvements as laminated disks, Alnico magnets, magnetic shielding provisions, and intricate die-cast mouldings, coupled with versatile engineering, multi-element meters became available which in some instances are about one-third the former weight and size. To those familiar with the many obstacles overcome to make such developments possible, there is great admiration for the initiative and perseverance which they represent.

Demand Meters

The fact that there is no nationally accepted standard unit of demand measurement has probably contributed to the lack of uniformity in electric utility requirements for demand-measuring devices. Furthermore, relatively small quantities of demand meters are used.

By the mid-twenties the concept of demand metering was firmly established and devices were available to meet various requirements. While both mechnical and thermal principles had been employed in different types of demand devices, most effort was being devoted to improvements in the mechanical types.

Mechanical demand devices are inherently complex due to the necessity of making provisions for the determination of time intervals and demand readings of the indicating, recording, or printing type.

In spite of the credit which must be accorded the development of several ingenious types of demand measuring devices, a need for further improvements became apparent as a means for reducing maintenance costs which were becoming more significant with the trend to measurement of demands for smaller loads.

It would be difficult to review in detail all the innovations and many mechanical refinements in various types of demand devices which have contributed to the substantially improved performance of those now available.

One particularly significant item was the introduction of higher-torque synchronous motors for controlling time intervals. This reduced motor failures which were a major factor in maintenance.

Demand-Register Scales and Markings

Those types of mechanical demand measuring devices which are incorporated as a part of the register of a watthour meter are called demand registers. Because the driving torque of demand registers is received from the shaft of the watthour meter it was necessary to establish a practical relationship between the new overload capacities of watthour meters and the demand which the register could record. This was accomplished through standardization wherein a reasonable number of specific demand scales were established which permitted demand readings consistent with the capacities of watthour meters.

Demand scale markings were also standardized to provide uniformity and consequent simplification of reading problems.

Cumulative Demand Registers

Demand registers are equipped with a demand pointer which indicates the highest integrated demand which occurs in a specific time interval. After a reading is taken it is necessary to reset this pointer to zero thus removing the possibility of a subsequent check of the reading. To overcome this situation cumulative-type demand registers were developed which have provisions for the retention of a cumulative-demand reading. This feature does necessitate a more complex mechanism but in those instances where the retention of a cumulative reading is deemed necessary it provides a most practical solution.

Recording Demand Meters

For the measurement of demand where a permanent record of successive readings is desired, graphic or printing-type demand meters are generally used. Much has been accomplished to improve the reliability of these instruments through electrical and mechanical refinements and more satisfactory materials. A subtractive feature was added to printing-type demand meters which simplifies interpretation of the printed records.

Improved tapes, sensitized charts, inks, heating devices, and other accessories related to the actual printing or recording have added to the dependability of these demand meters particularly under adverse conditions.

Totalizing Devices

Demand metering frequently involves the determination of the coincident demand of two or more watthour meters. If graphic or printing-type demand meters are used with each watthour meter the coincident demand is determined only by a correlated interpretation of the graphs or charts. If individual indicating-type demand meters are used the coincident demand cannot be determined. To avoid either condition, suitable totalizing mechanisms have been developed which permit the indicating or recording of totalized coincident demand for two or more watthour meters on one

demand meter. This not only facilitates the determination of a single-billing demand but affords economies in metering investment.

Kva Demand Meters

The most commonly used unit of demand measurement is the kilowatt. However, there are situations involving a consideration of power factor where it is desirable for either billing or load-study purposes to measure kilovolt-ampere demand. Various methods and devices have been developed for the metering of kva demand. These involve many very interesting and unique means for determining the equivalent of a vector analysis of circuit conditions.

Thermal-Type Demand Meters

A trend in demand metering in recent years has been a renewal of interest in and the further development of thermal-type demand meters. This type of demand meter is activiated by heating developed from the energy being measured and is not dependent upon the operation of watthour meters.

Thermal-demand meters are relatively simple in respect to mechanical construction which is conducive to a lower maintenance cost. They are now available with standardized ratings and scales and incorporated with watthour meters in a manner similar to demand registers. This places them on a common basis with other demand devices in respect to installation practices.

Inherently, thermal-demand meters represent a somewhat different concept of demand measurement and differ from most mechanical demand devices in the manner in which they respond under similar conditions. This difference is no deterrent to the adoption of either type but should be understood when considering their application.

Instrument Transformers

In addition to watthour and demand meters, instrument transformers represent the third general category of metering equipment which has undergone interesting and substantial improvements in the past twenty-five years. Current and potential transformers are required in metering where amperes and voltages to be metered exceed practical limits for direct metering. Instrument transformers reduce these values by accurate ratios which facilitate metering and yet permit the proper determination of metered quantities.

One of the more noteworthy improvements in instrument transformers is the exceptionally fine ratio and phase-angle characteristics which have been obtained thus minimizing metering errors from this source.

The growth of low-voltage power distribution increased the need for current transformers and, similar to the situation which existed in respect to watthour meters, there was a pressing need for transformers with a broader range to meet load growth trends and avoid excessive replacement and stockkeeping requirements.

Another item of concern to electric utilities was the variation of terminal and mounting dimensions between various sizes and types which hampered the interchangeability of transformers.

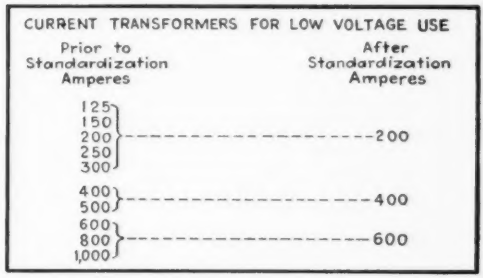


FIG 6—STANDARDIZATION reduced number of low-voltage current transformers by cultivating long-range characteristics

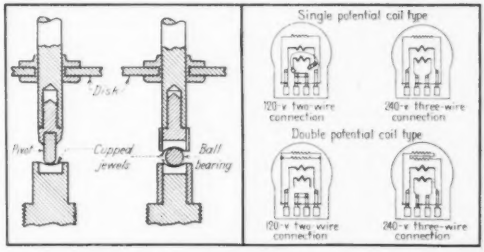


FIG 7—DOMINANT PIVOT BEARING for watthour meters of the mid-twenties yielded to the ball-bearing of the mid-forties

FIG 8—TYPICAL CONNECTIONS for convertible designs of two-wire/three-wire meters to meet expanding loads

Through the joint efforts of manufacturers and electric utility representatives a pattern of improvements, similar to that for watthour meters, has been accomplished in respect to instrument transformers.

Instrument Transformer Insulation

Standards established for instrument transformers include specifications for tests which coordinate insulation requirements with respect to protective devices and possible system over-voltages. The adoption of these standards has provided more protection for meters and prevented hazards caused by transformer insulation failure.

Through-Type Current Transformers

A development directed principally toward providing a less costly current transformer and reducing installation expense was the development of the through-type current transformer, having accuracy acceptable for metering, in ratings as low as 200 amp. Because the current-carrying conductor passes through an opening in the transformer, mounting and connecting facilities are simplified.

Low-Voltage Current Transformers

A most significant advancement in respect to instrument transformers was the standardization of low-voltage current transformers. Prior to this time it

was common practice to use transformers designed principally for substation and other high-voltage metering installations. These transformers did not permit a full realization of the possible installation economies and lower maintenance costs.

The standardization which was effected, provided for: the establishment of a specific group of current transformers for low-voltage metering which included only the three sizes of 200, 400, and 600 amp; increased overload capacity; a higher level of accuracy; and standardized mounting dimensions.

Primary Bar-Type Transformers

As might be expected, the successful standardization of low-voltage current transformers focused attention on the need for a similar development for high-voltages transformers applicable to primary circuits. A substantial contribution in providing flexibility and economy of installation and replacement was made by the subsequent standardization of primary terminal and mounting dimensions of primary current transformers up to 15-k ratings.

Potential Transformers

Potential transformers are generally employed for only the relatively few high-voltage metering installations. Though fewer in number than current transformers they are important in respect to the metering of large quantities of electric energy metered at primary voltages. It is most important that potential transformers maintain a high level of accuracy. By the successful application of improved insulation and design features the failure or improper performance of potential transformers has become an exceptionally rare occurrence.

Future Objectives

To present a twenty-five year review of the advancement of a subject with as many elements as electric metering and remain within reasonable limits creates a probability that over-simplification may detract from a proper understanding of the unprecedented technical advancement and standardization which were accomplished only through an inspired desire to meet never ending challenges.

The manner in which metering in this country has reached its present high level is a story in itself. It is a singular example of the cooperative effort of individuals and organizations to which many have devoted a lifetime of work.

In reviewing the improvements in metering, it is significant to note the underlying emphasis to attain more accurate and dependable metering equipment which would bring about lower costs and reduced maintenance expense. In the accomplishment of this aim, metering has contributed materially to the ability of electric utilities to economically furnish more electricity to more customers.

Probably the most convincing evidence of the progress made in metering is the widespread adoption of extended periodic-test schedules. For example: In the last twenty-five years, the schedule, generally recognized as appropriate for small a-c watt-hour meters, has extended from three to eight years.

For those who may regard standardization with some apprehension, there are few finer examples of practical standardization than is represented in the advancement in metering. Standardization requires cooperation and some compromise but it is through such action, that more satisfactory results are obtained. There is every indication that the benefits are shared mutually by manufacturers, electric utilities and users.

Pending Issues

Satisfying as it may be to reflect on past accomplishments there remains the need to give attention to current problems and endeavor to establish desired goals which may be recorded as accomplishments at some future time.

There are some who suggest there is a possibility that the number of meter ratings could be further reduced and that meter capacities could be made larger to lessen the need for the more costly transformer installations.

It would be foolish to say that such developments are impossible; but only the thoughtful application of engineering and a consideration of the economics involved will determine if such goals are feasible and worthy of attainment.

It is reasonable to assume that continued effort will be made to seek modifications in meter design and the use of alternate materials which will keep manufacturing costs at the lowest possible level.

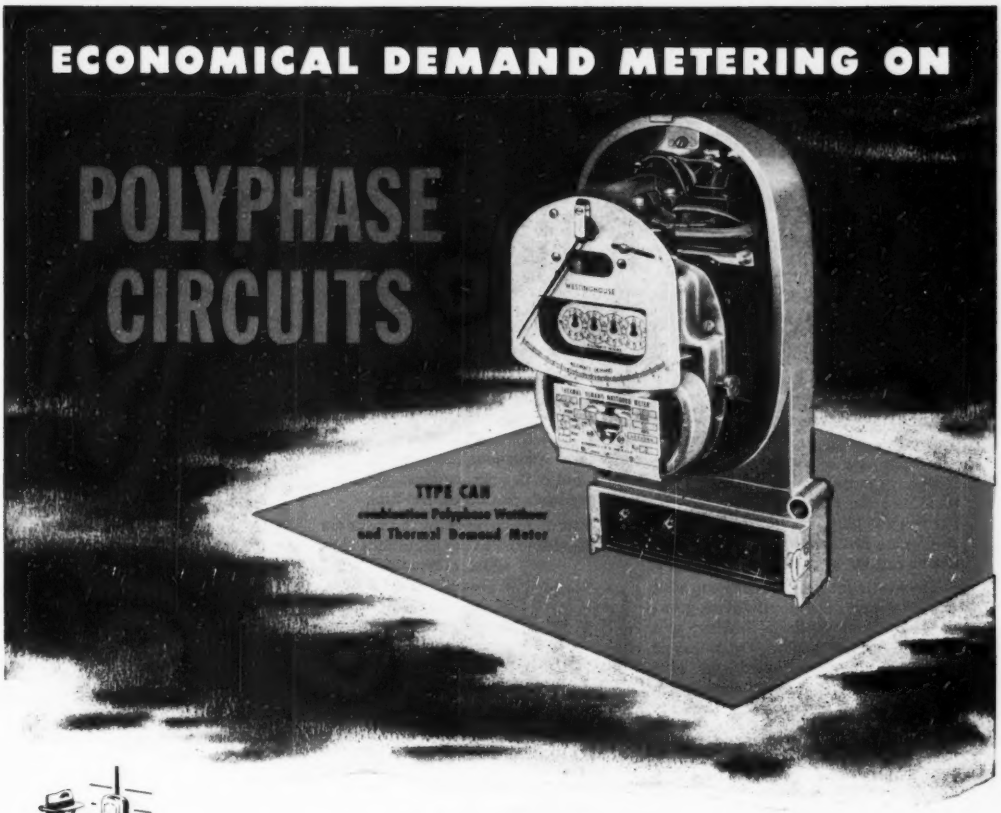
The burden of obtaining lower cost metering does not rest entirely with the manufacturers. There still remains many advantages to be gained through adoption of even more uniform metering practices among electric utilities. There are certain economic barriers which do make difficult the adoption on the part of electric utilities of all new standards but experience has been most gratifying in this respect.

Demand metering presents one of the more conspicuous examples where more consistency in the requirements for demand measurement, as specified in rate structures or set forth in other interpretations, would be beneficial in reducing the variety of demand meters requested from manufacturers. While this involves considerations outside the scope of metering it does not lessen the obligation of those engaged in metering to foster a more general awareness of the advantages to be gained from simplified metering requirements.

There has been little discussion on meter-installation practices as it was intended that the emphasis be on metering. However, the importance to electric utilities of installation methods and meter-connection equipment is demonstrated by the amount of attention which this subject is currently receiving and will probably continue to receive.

As we review and record briefly the progress in metering during the past twenty-five years there arises the inevitable conclusion that much has been accomplished but more remains to be done. It would be disheartening to have it otherwise.

ECONOMICAL DEMAND METERING ON POLYPHASE CIRCUITS



...even where the load is small!

Here's your answer to the problem of low-cost demand metering on polyphase circuits . . . for the *full range* of loads.

YOU CAN BE SURE..
IF IT'S
Westinghouse

New, low-cost Westinghouse polyphase Demand Meters combine a standard polyphase Watthour Meter and a Thermal Demand Meter into *one* compact unit. Their inherently low maintenance characteristics make possible the sound economy of demand metering on small *or* large loads. Only one mounting is required . . . taking up little more space than one three-element polyphase Watthour Meter. Installation is greatly simplified. A low first cost is made possible through simplified design.

Whatever your requirements may be . . . kw *or* kva demand meters . . . single-phase or polyphase . . . Westinghouse has the meter that will give you the *accurate* and *economical* information you need. For complete information call your nearest Westinghouse office or write for C. S. 42-338, Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pennsylvania. J-40364

Westinghouse
PLANTS IN 25 CITIES . . . OFFICES EVERYWHERE

Watthour and Demand Meters for Any Job

50 YEARS OF METERING PROGRESS

by

SANGAMO

Five hundred and forty (540) electric meters in one year! That was the total production of Sangamo Meters in 1899—the first year of the Sangamo Electric Company's incorporation. Production was small and the meters far from perfect, but this was only 17 years after Thomas A. Edison's first utility central station became a reality.

The first dozen years of Sangamo were years of struggle that paralleled the growing pains of the Electrical Industry as a whole. But from then on, production of Sangamo Meters multiplied year after year—in step with the growth requirements of the Industry. Today, the production of Sangamo Meters of all types annually totals more than a million!

From the very beginning (and continuing today) Sangamo's major effort was concentrated on research and development, and on sound and skillful engineering principles in practicing the art of metering—all to keep in step with, and anticipate, the constantly changing requirements of a growing Electric Utility Industry. The first Sangamo Meter, the Gutmann model, was the result of this type of effort. A few small orders for this original model in 1899 established Sangamo as a going business.

Gutmann Model 1899 (without cover)

The development and marketing of the second model, the Sangamo Type H Watthour Meter came in 1911. That year was a milestone in Sangamo's growth. The first sizeable order for H meters required expansion of the previously small engineering staff. This expanded staff, too, had the task of coping with the metering problems of a rapidly growing Electric Utility Industry.

Type H Watthour Meter

Because Sangamo Meters satisfactorily met the performance requirements of that period, a continuously increasing number of meter installations, including both the D. C. and A. C. types, required expansion of Sangamo's production facilities.

A part of Sangamo's growth in this era was also due to its ability to meet the electrical measurement requirements of other fields. The development of Sangamo Mercury Motor Meters for direct current was an outgrowth of a ready market for these meters for home generating plants, electric autos, street railway systems, and other applications where storage batteries were used for power. Some of these power applications were later superseded by newer developments, which resulted in a decline of mercury motor meter usage, but coincidentally, increased the need for other watthour meters.

Mercury Motor Meter

Production requirements caused by World War I stimulated greater application of electric power for industrial usage. This kind of power usage, in turn, made it imperative for Electric Utilities to supply new, accurate devices suited for measuring these loads. Anticipating this requirement, in 1914, Sangamo Engineers started on the development of a small synchronous motor to provide accurate timing for demand registers. In 1923 the first synchronous motor-driven demand register was marketed by Sangamo. Further development of small synchronous motors, based on that original design, continues to this day.

Demand Register

Lincoln Thermal Demand Meters, which Sangamo introduced on the American market in 1928, were based on the Industry's need for a demand meter requiring little or no maintenance. Their basic principle of measurement now has wide general acceptance in the Industry.

Lincoln Thermal Demand Meter

The ten-year growth cycle of the Electrical Industry beginning in 1920, brought on metering problems which were caused by the application of new commercial policies and rate-making theories in the sale of electric service. This cycle received its impetus from the intense promotion of electric appliances for residential use. Coincidental with these developments, which were confined to singlephase service requirements, there were also to be solved the new problems of accurate measurement of polyphase power for constantly expanding industrial applications. By about 1928 the increased use of the wye-network system of distribution in congested areas spotlighted the necessity for smaller and lower cost polyphase meters.

Sangamo's first contribution to smaller, lower cost polyphase meter installations was the Type L. This meter was later improved and redesignated in 1941 as the Sangamo Type LC Polyphase Meter.

Type L Polyphase Meter

At the turn into the thirties there came the anticipation of popular use of electric water heaters and ranges, and the adoption of a new form of rate for this usage. A new device to measure and control these loads was required. This control device, for off-peak water heating, was the Sangamo Time Switch. It made its debut in 1930. Later, in 1933, again foreseeing the

Combination Meter-Time Switch

needs of the Industry, Sangamo first produced its combination meter-time switch.

Type HFA Meter

When, in 1933, the Industry required standardization of mounting and terminals, the Sangamo Types HFA, HFB, HFC, and HFS Meters were introduced. These meters were really the "grown-up" brothers of the old Type H Meter of 1911. The 1911 models had undergone an important change in 1914, the modification of their electromagnetic structure, and were at that time renamed the Type H-2. In 1928, because of the trend toward outdoor installations and increasing loads, compensation for temperature and overload was incorporated, and the designation was changed to Type HC.

Type HFS Meter

Type HC Meter—1928

By 1940, the complex range of the loads, the necessity for greater overload capacity, the more rigorous conditions imposed by outdoor installations, and requirements for simplified construction to accommodate easier testing and replacement of parts, called for a radically new meter design. A meter, designed and constructed to meet these more severe conditions of service, and in addition, to anticipate metering requirements of the future, was presented to the Utility Industry as the Sangamo Type J Meter. Since 1940 when the Type J was introduced, the performance of several million of these meters in actual service has proven the following advantages of the Sangamo Type J design:

Overload compensation and other inherent overload characteristics to measure accurately present *and* future *loads up to 400% of meter rating without loss of revenue.*

Surge-proof alnico damping magnets to eliminate over-registration and to reduce "high hill" complaints.

Potential and current coils with high insulation levels to minimize lost registration and service failures due to lightning.

High arc track resistant insulating materials for terminal blocks and bushings —an important feature on new sequence connection in reducing service interruption, hazards, and costs.

Modern improved upper and lower bearings—oilless, noiseless, non-corrosive and rustproof in all climates, to contribute to high accuracy with long periods between tests.

Corrosion-resistant materials, and full temperature compensation, for cost-saving outdoor installations.

Wide-range micrometer type full load and light load adjustments for exact and easy calibration.

Driving element with current and potential elements dovetailed and rigidly held together for sustained accuracy, but easily separable for individual and inexpensive replacement.

Accessibility of all parts for easy and low cost calibration, inspection, and replacements.

Sangamo's meter designs of today are the culmination of 50 years' experience in continuous research, in the development, and in the specialized manufacturing of electric meters to meet the Industry's needs. These meters have *proved*, by years of service, their ability to meet the requirements of today and the anticipated loads of the future with sustained accuracy, economy of maintenance, and troublefree performance.

Sangamo's engineering "know-how" and skills in the past have been flexible and adaptable. They will be geared in the future to keep in step with the continuously changing measurement problems and rate practices of the Electric Utility Industry.

No other Commodity is measured so Accurately as Electric Energy

50TH ANNIVERSARY
SANGAMO
1899 - 1949

SANGAMO

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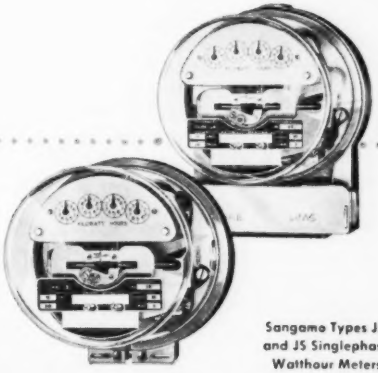
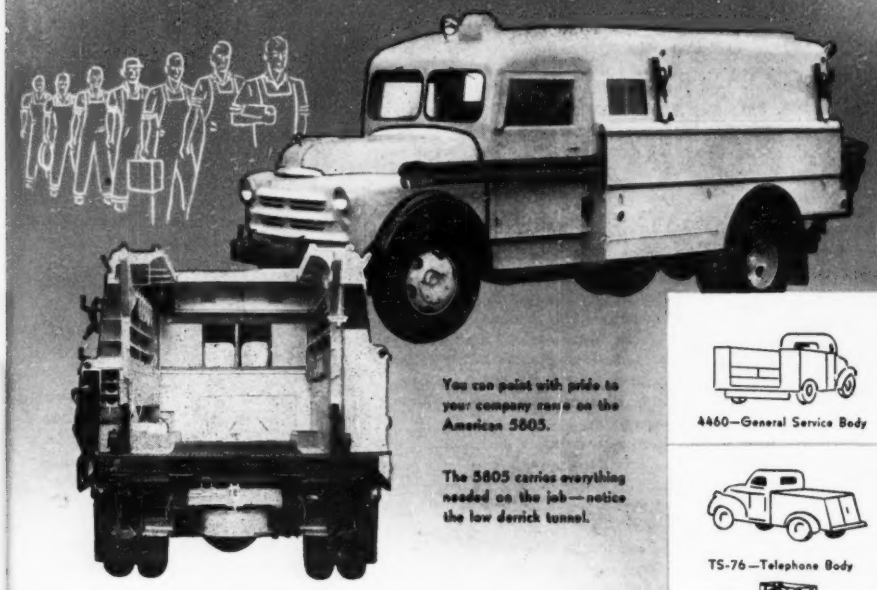


Sangamo Types JA and JS Singlephase Watthour Meters

SM-49B

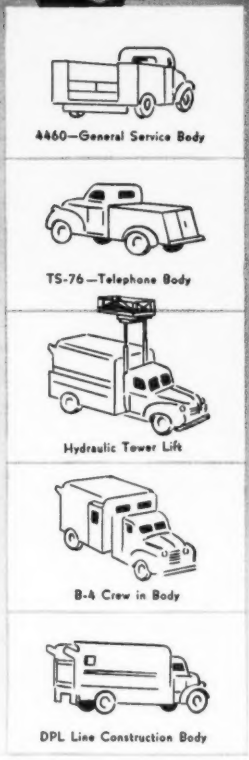
American 5805

7-MAN CREW COMPARTMENT LINE CONSTRUCTION BODY



You can paint with pride to your company name on the American 5805.

The 5805 carries everything needed on the job—notice the low derrick tunnel.



designed for extra wide hood and fender lines

Crews like the idea of a 7-man compartment, integral with body. Good visibility, ventilation and padded seats add to crew comfort. Cab easily accessible from both sides of body. Hinged front seat permits easy entrance to rear seat. Streamlined compartment utilizes space available on the current wide models of truck chassis.

Body is exclusive American line construction design with a place for ladders, pike poles, derricks and the dozens of other items (large and small) needed on the job. Available in basic length of 138 inches.

This 7-man crew compartment body, replacing Model 3714, has been a long-time favorite with light, gas, water, telephone, municipalities and contractors.

Ask The American Coach & Body Company about Model 5805, streamlined for the extra wide hood and fender lines.

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ACB and

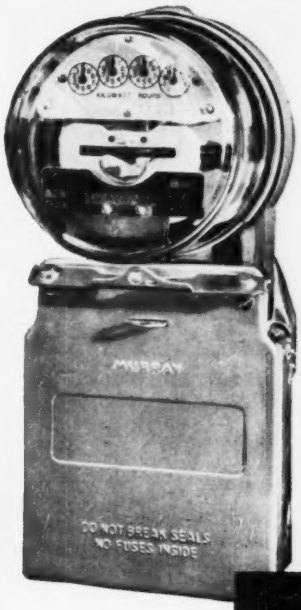
Indoors . . . Outdoors

THE

Murray "9600"

Meter Connection Box

IS BUILT TO LAST



Dependable, trouble free service is yours with the versatile "All-Service" Murray "9600" Meter Connection Box. Designed to accommodate modern bottom-connected Type A watthour meters, it is eminently satisfactory for either indoor or outdoor mounting. Available in either unpainted aluminum or rust-resisting steel with baked-on gray melamine finish.

Greater depth provides 20% more wiring space. Only one seal is needed — hinged sealing cover does away with sealing studs and bar. Complete with meter test and connection block, and four formed copper test links. Detailed specifications are given in Bulletin No. 501.

Plenty of hand room is provided in this compact Murray Aluminum Socket. Solderless terminals take up to No. 1 wire. Two types—with or without 1" knockout in back. Cat. No. 1540.

Multiple meter mountings are simplified with this typical Murray Three Gang trough. Similar troughs are available to accommodate two to six meters. Cat. No. 583.

FOR TOMORROW'S LOADS . . .

Equip Today!

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SERVICE ENTRANCE & METER EQUIPMENT • MAGNETIC CIRCUIT BREAKERS
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the TOOL and the SLEEVE

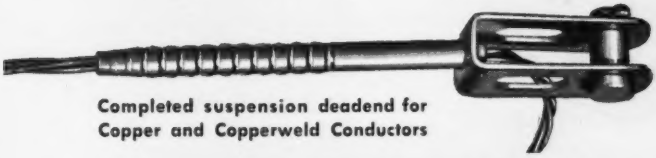
that are made to work together

TOGETHER

they make the perfect splice

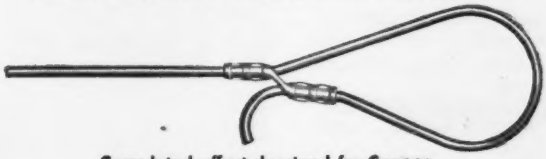
Completed splice on Solid Copper Conductor

Completed splice on Copperweld Conductor



Completed suspension deadend for
Copper and Copperweld Conductors

Partially completed reinforcing sleeve on Copperweld



Completed offset deadend for Copper
or Copperweld Conductors

● ***Nicopress sleeves and tools are available in a complete range of sizes for Copper, Copperweld-Copper, A.C.S.R. and Steel Conductors.***

Illustration of No. 51 type Nicopress tool with P. & J. Grooves.

The National Telephone Supply Company

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NOW...A POLE DERRICK WITH 45% LESS WEIGHT!

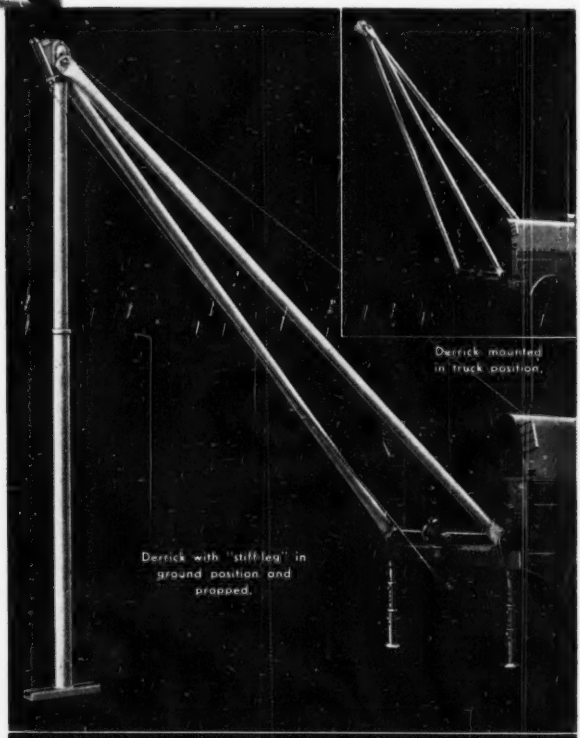
Derrick side — legs easily handled by one man.

The FWD *Aluminum* DERRICK

- All legs of strong, structural ALUMINUM — 45% less weight — easy handling.
- Legs have reinforced, die-formed heads for greater strength.
- Derrick head equipped with roller guides — for cable protection and longer cable service life.
- Less set-up time required—greater safety for crew men — lighter weight side-legs can be easily handled by one man.
- "Stiff-leg" telescopic with free, easy adjustment to various heights.
- Telescopic side-legs provide for compact, easy transportation.
- Available in 2 models of tripod type derricks. Pole size handling range up to 55 ft., lifting capacity range up to 7200 lbs. in truck position and up to 12,000 lbs. with "stiff-leg" in ground position.

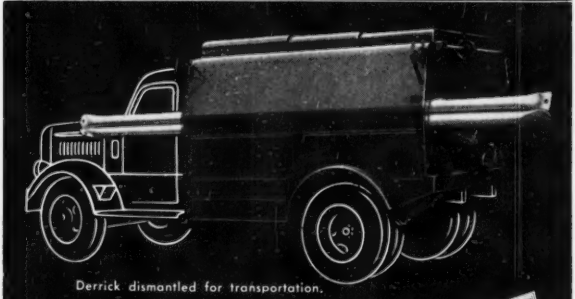
This modern, strong, dependable, all-aluminum pole derrick answers a long-felt need and offers the important advantage of 45% less weight. It was developed and perfected by FWD—a specialized manufacturer of utility line construction-maintenance tools and equipment, engineered by and for utility men expressly for their needs.

For complete information and prices see your Graybar Distributor or write—Eagle Manufacturing Co., 414 E. Winnebago Street, Appleton, Wisconsin.



Derrick mounted in truck position.

Derrick with "stiff-leg" in ground position and propped.



Derrick dismantled for transportation.

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Write today for the complete catalog of FWD Line Construction and Maintenance Equipment — a useful reference catalog.

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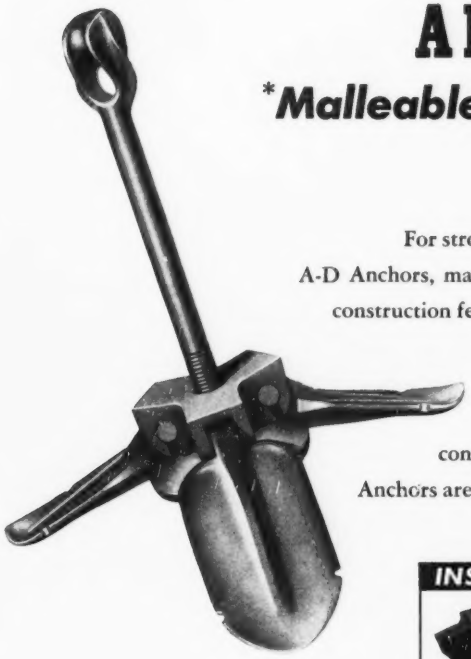
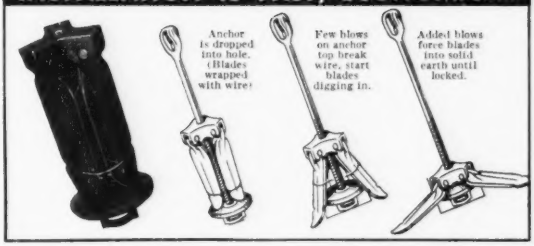
*Malleable Iron, Expanding Type ANCHORS



For strong, durable, *reliable* anchors, you can depend on A-D Anchors, made of high-strength malleable iron. Design and construction features of A-D Anchors assure holding power and *lasting* strength. Three long blades dig into solid earth and lock — for perfectly distributed pulling resistance under all conditions. Approved by the R. E. A., Albion-Dillon Anchors are preferred by utility companies for dependability.

*Albion-Dillon Anchors are made of high-strength malleable iron, with its high tensile strength, toughness and resistance to corrosion.

INSTALLATION IS FAST, ECONOMICAL


Anchor is dropped into hole. (Blades wrapped with wire)
Few blows on anchor top break wire, start blades digging in.
Added blows force blades into solid earth until locked.

SPECIFICATIONS

Cat. No.	Hole Size	Spread	Sq. Inch Area of Anchor	Sq. Inch Area in Undisturbed Earth	Rod Size	Wt. Pounds per 100	Holding Power (Pounds)		
							Ordinary	Clay	Hard Pan
3-34	3"	11"	34	26.70	½"-⅝"	365	2500	4000	5500
4-64	4"	15"	64	51.24	⅝"-¾"	825	8000	10000	13000
6-118	6"	18"	118	89.40	⅝"-¾"	1100	12500	19000	25000
6-133	6"	20½"	137	105	⅝"-¾"	1300	14000	20000	26000

ALBION MALLEABLE IRON CO. 1888

ALBION MALLEABLE IRON CO.

"One of America's Foremost Producers of Malleable Iron"

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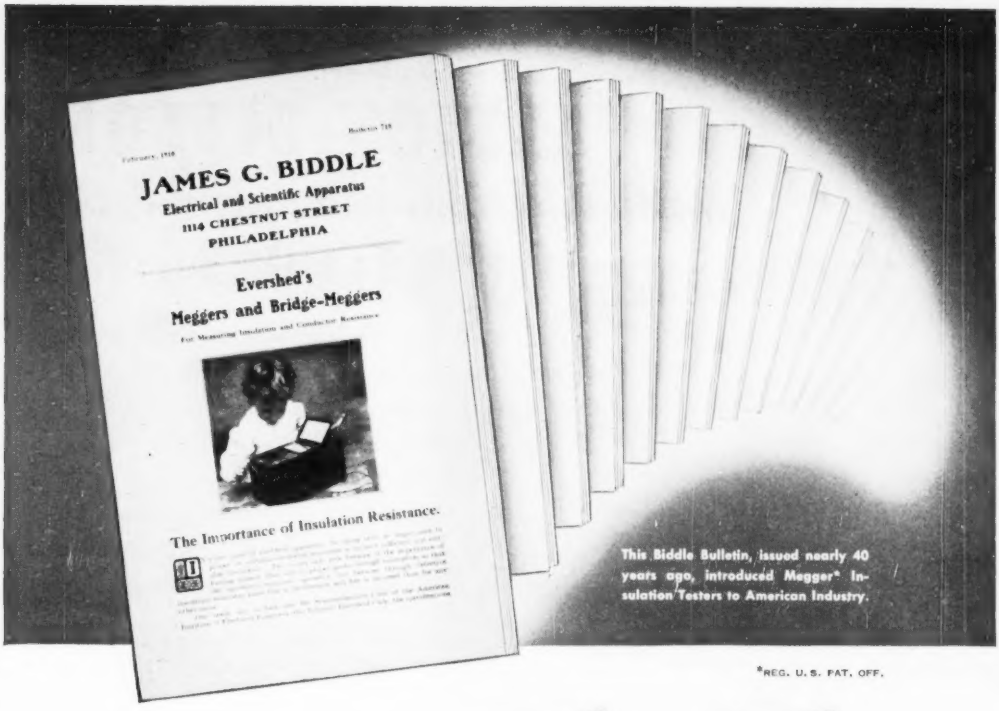
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The Importance of Insulation Resistance.
This Biddle Bulletin, issued nearly 40 years ago, introduced Megger* Insulation Testers to American Industry.

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FOR over half a century the family of Biddle Bulletins has been a barometer of the continuous development and expansion in the line of Biddle instruments. To the original Megger Insulation Tester featured in the old bulletin illustrated above, many unique and outstanding Biddle products have been added. Higher range Megger Insulation Testers and small "popular" models have been developed together with Megger Ground Resistance Testers, and Ducter Ohmmeters for measuring low resistance. A recent important development is the "TTR" Set, for determining transformer turn ratios. Also, an ever-increasing variety of Frahm Resonant Reed instruments for measuring speeds, frequencies and rates of vibration flows to nearly every branch of industry from the Biddle plant.

And it is the responsibility of Biddle Research and Development engineers to make continuing contributions in the form of new and improved instruments—to meet new requirements and to answer new demands as they develop. Never overlook the advantages of keeping fully up-to-date on Biddle instruments—by means of Biddle Bulletins.

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IMPORTANT NEWS!
for users of Aluminum
United States Steel Supply Company
has added aluminum to its line of products
Warehouses of the United States Steel Supply Company are now arranging to carry in stock a complete line of aluminum mill and building products manufactured by the Reynolds Metals Company.
This is further indication of the far-reaching expansion program of United States Steel Supply Company and its desire to satisfy more completely the metal requirements of its customers.
Initially, aluminum mill products — such as structurals, bars and sheets are stocked at the firm's Los Angeles, San Francisco, and Chicago warehouses.
Aluminum building products such as corrugated sheets, siding and other materials are in stock at Newark, Baltimore, Chicago, St. Paul, Milwaukee, St. Louis, Los Angeles and San Francisco warehouses.
Experienced technicians will be at customers' disposal at all times to help with problems involving application or fabrication.
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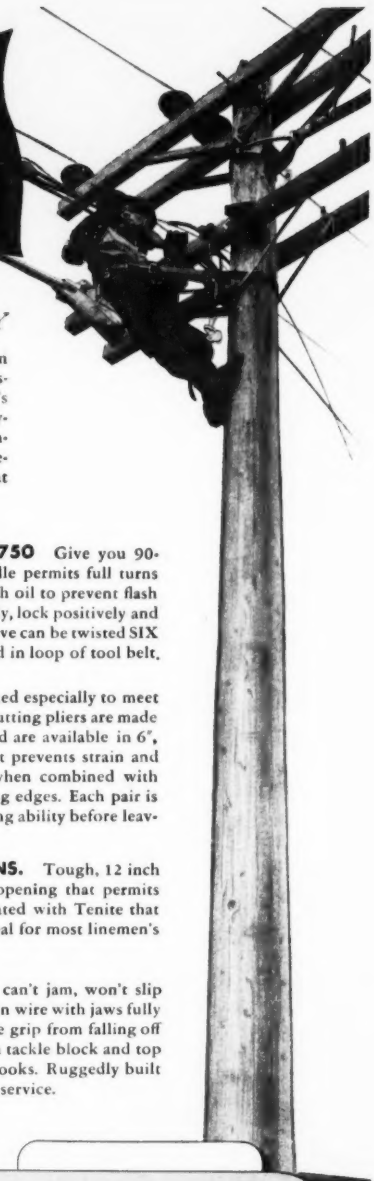
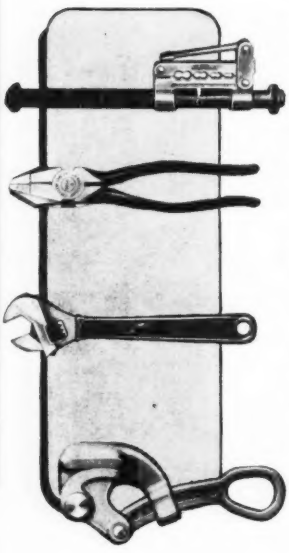


Specialized Tools for the ELECTRICAL INDUSTRY

For over 40 years, the Crescent Tool Company has worked closely with the Electrical Industry in developing tools that exactly fit the needs of their workers. While *all* Crescent Tools must pass rigid laboratory tests before they can bear the Crescent label, the electrical tools in the line were made up in small quantities and tested in the field and improved by the suggestions of linemen, themselves. That's why, today, electrical workers everywhere, insist on Crescent quality; insist on Crescent thoroughness in designing, testing and improving that has made their job easier.

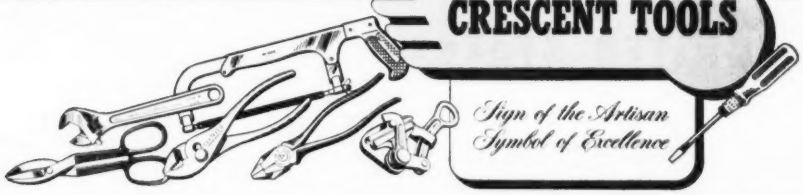


CRESCENT SLEEVE WRENCHES #750 Give you 90-98% perfect joints. Sliding hickory handle permits full turns in close quarters and is impregnated with oil to prevent flash if contacted with hot wire. Jaws close easily, lock positively and can be readily released with one hand. Sleeve can be twisted SIX full turns without cracking. Easily carried in loop of tool belt.

LINEMEN'S PLIERS 1950 Designed especially to meet the requirements of linemen, these side cutting pliers are made of super tough, forged Crestoloy steel and are available in 6", 7" and 8" sizes. Precision machined joint prevents strain and insures perfect jaw alignment, which, when combined with hard tempered head provides keen cutting edges. Each pair is individually tested for strength and cutting ability before leaving our factory.

INSULATED WRENCHES AC-112-INS. Tough, 12 inch adjustable Crestoloy wrench with 1½" opening that permits them to handle 4/0 taps. Heavily insulated with Tenite that won't crack or chip off, this wrench is ideal for most linemen's requirements.

WIRE GRIPS Crescent Wire Grips can't jam, won't slip and will release instantly. Easy to place on wire with jaws fully open, a special hook locks to prevent the grip from falling off wire. Large eye to accommodate hook on tackle block and top ring is provided for use with hot line hooks. Ruggedly built throughout for a life-time of heavy duty service.



CRESCENT TOOLS

Sign of the Artisan
Symbol of Excellence

"Crescent" is our trade-mark, registered in the United States and abroad, for wrenches and other tools. Sold by leading distributors and retailers everywhere and made only by

CRESCENT TOOL COMPANY, JAMESTOWN, NEW YORK

You can do a lot

with a little GOLD SEAL TAPE

That's one of the first things you notice about Gold Seal Tape—*it goes further.* There's more tape value in every roll because there's no waste.

Laboratory controlled production assures lasting "tack" in the friction compound. Gold Seal will not dry out or peel. Its top quality base cloth tears evenly, quickly, without raveling.

Hot or cold . . . rain or shine . . . here's a tape you can depend on to stick to the job—speed the work. Try Gold Seal—see why this "best buy in tape" is the lasting favorite of linemen and electricians.

In single rolls and handy ten-roll containers. Each roll is cellophane wrapped —*factory-fresh.* Jenkins Bros. (Rubber Division), 80 White St., New York 13.

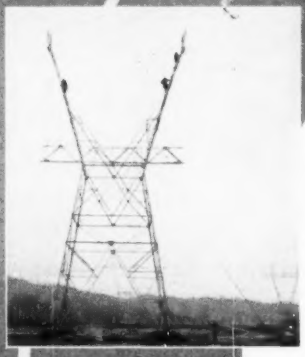
Jenkins Bros. also make Diamond Seal Friction and Rubber Tapes which meet both ASTM and Federal Specifications.

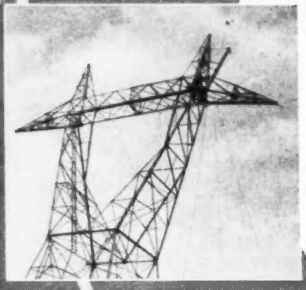
JENKINS Gold Seal Tape

FRICTION and RUBBER TAPES

MADE BY JENKINS BROS. . . . MAKERS OF FAMOUS JENKINS VALVES

"KNOW-HOW" *and* EXPERIENCE *are combined in* COLLIER CONSTRUCTION WORK





Whether your work requires stringing high voltage lines—erection of towers—or installation of electrical equipment from power house generator to industrial plant distribution systems—Collier offers both the "know-how" and experience to handle the job.

With a background of several years serving a number of leading mid-west and eastern utility companies Collier has the organization and facilities to handle your line construction and wiring jobs.

In addition Collier also has available a Staff of competent engineers to design your transmission lines and river crossing projects.

Transmission Lines
Underground and Overhead Distribution
Industrial Plants
Substations
Street Lighting
Power Plants

THE COLLIER CONSTRUCTION COMPANY

Electrical Engineers and Contractors

FILM EXCHANGE BLDG. CLEVELAND 14, OHIO

MARMON-HERRINGTON
All·Wheel·Drive

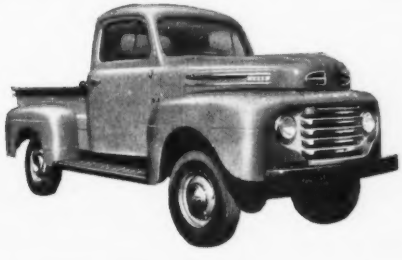
Big Trucks—and Small for Every Tough Job Call

In the Marmon-Herrington line you will find an *All-Wheel-Drive* truck—*with the right power, in the right capacity*—to fit every tough line and construction job, however big or small.

Marmon-Herrington offers twenty-two *All-Wheel-Drive* models in all. Four are heavy-duty models of the company's own manufacture; the balance are standard Ford models converted to *All-Wheel-Drive* by Marmon-Herrington. Wheelbases range from 110 inches to 220 inches—gross vehicle weights from 5,300 pounds to 42,000 pounds. There are 7 great engines, Diesel and gasoline—from 4 to 10 forward speeds, 1 to 4 reverse.

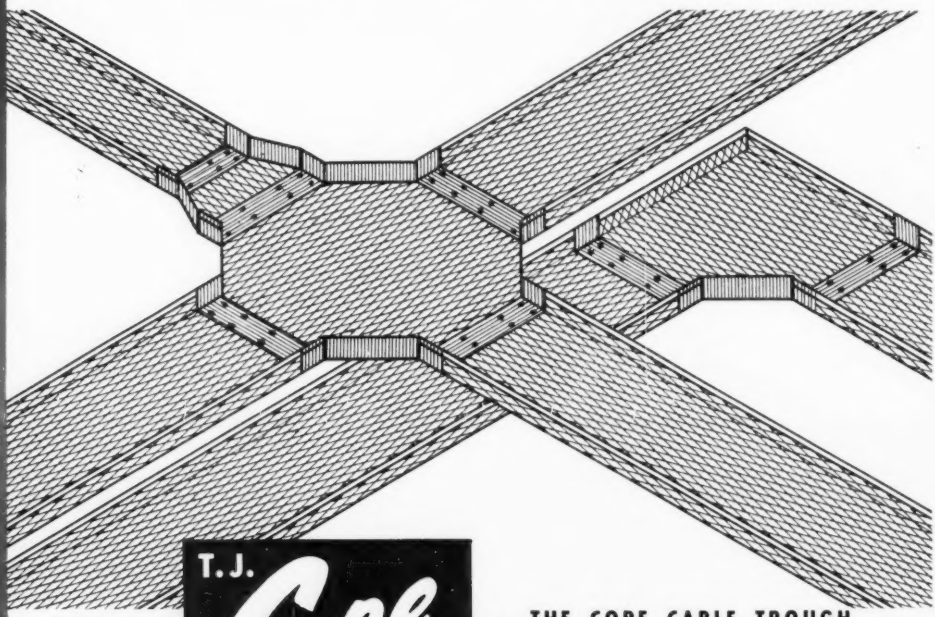
Live power and traction in all wheels—*front wheels pulling, rear wheels pushing*—give Marmon-Herringtons tremendous tractive power for toughest off-the-road operations . . . no mud too deep, no hill too steep, no going too rough and rugged. Let your Marmon-Herrington dealer give you an on-the-job demonstration of these great *All-Wheel-Drive* trucks. You'll witness an eye-opening brand of performance-ability.

MARMON-HERRINGTON COMPANY, INC. • INDIANAPOLIS 7, INDIANA



MARMON-HERRINGTON
All·Wheel·Drive

Are you keeping pace with



T. J. Cope INC.

THE COPE CABLE TROUGH

These are *Only* Two of the Many Cope Products which are Speeding Work and Saving Money in the Utility Field

You know Cope by these products

the Electrical Industry?

THE COPE PNEUMATIC FISH LINE

T. J. Cope INC.

For over 60 years Cope has been working with the pacemakers. As the industry grew, new materials, new procedures, new methods, were introduced, which in turn demanded new tools. Cope was on the job.

Some of these tools were inspired by the men in the field. Some were anticipated by Cope. Some were the result of cooperative effort.

Illustrated here are two such examples of Cope developments. The cable trough is a ready-made system of troughs which eliminate engineering detail and simplify trough installations—troughs that can be used for electrical control cables or for instrument tubing.

The Cope Pneumatic Fish Line, which makes it possible to fish underground ducts in a matter of minutes, and to eliminate operations from rodding procedures, is a device that has shown savings as great as 58 minutes of each rodding hour and has proven its value in rodding ducts of many sizes and lengths, some as large as 8″ in diameter and some as long as 1750 feet. Model A has the unique feature of a power operated reel. An air motor is provided to re-reel the stranded wire to which certain tools can be attached.

Cope has a new catalog. Request your copy today.

T. J. COPE, INC.— 711 So. 50th Street, Philadelphia 43, Pa.

America Wants Value . . . America Buys

CHEVROLET ADVANCE-DESIGN TRUCKS

America's truck operators know that these all-star cargo carriers deliver the goods all along the line—in power, stability, stamina, handling ease, comfort and convenience. They know—and they buy and operate more Chevrolet trucks than any other make. And in owning the nation's Number 1 truck, they enjoy *lower cost* of operation, *lower cost* of upkeep and the *lowest list prices in the entire truck field!*

CHEVROLET MOTOR DIVISION, *General Motors Corporation*, DETROIT 2, MICHIGAN

Chevrolet's the *Only* Truck With All These Features

NEW CHEVROLET 4-SPEED SYNCHRO-MESH TRUCK TRANSMISSION

A special feature in Series 3800 and heavier duty models that assures new operating ease and efficiency.

THE CAB THAT "BREATHES"

Here are the trucks with the famous cab that "breathes"! Outside air is drawn in and used air is forced out! Heated in cold weather.*

FLEXI-MOUNTED CAB

Chevrolet's Advance-Design Cab is mounted on rubber, cushioned against road shocks, torsion and vibration.

IMPROVED VALVE-IN-HEAD ENGINE

The world's most economical engine for its size now has greater durability and operating efficiency.

SPLINED REAR AXLE HUB CONNECTION

Greater strength and durability in heavy-duty models with this exclusive Advance-Design feature.

PLUS Uniweld, all-steel cab construction • New, heavier springs • Full-floating hypoid rear axles on the 3600 Series and heavier duty models • All-round visibility with rear corner windows* • Specially designed brakes • Hydrovac power brakes on Series 5000 and 6000 models • Ball-bearing steering • Double-line pre-selective power shift in 2-speed axle at extra cost on Series 5000 and 6000 models • Wide-base wheels • Standard cab-to-axle-length dimensions • Multiple color options.

**Heating and ventilating system and rear corner windows with de luxe equipment optional at extra cost.*

CHEVROLET

CHOOSE CHEVROLET TRUCKS FOR TRANSPORTATION UNLIMITED!

HUBBARD round end crossarm braces are NEW

1. The only flat steel brace made exclusively with rounded ends.
2. No jagged or sharp corners to catch on clothing or equipment.
3. Made in all communication and power standards.
4. Lengths from 20 to 32-inches. Made from 1-7/32 by 7/32 inch or 1-¼ by ¼ inch steel.
5. Protective coating—Hubbard Double Dip Hot Galvanizing.

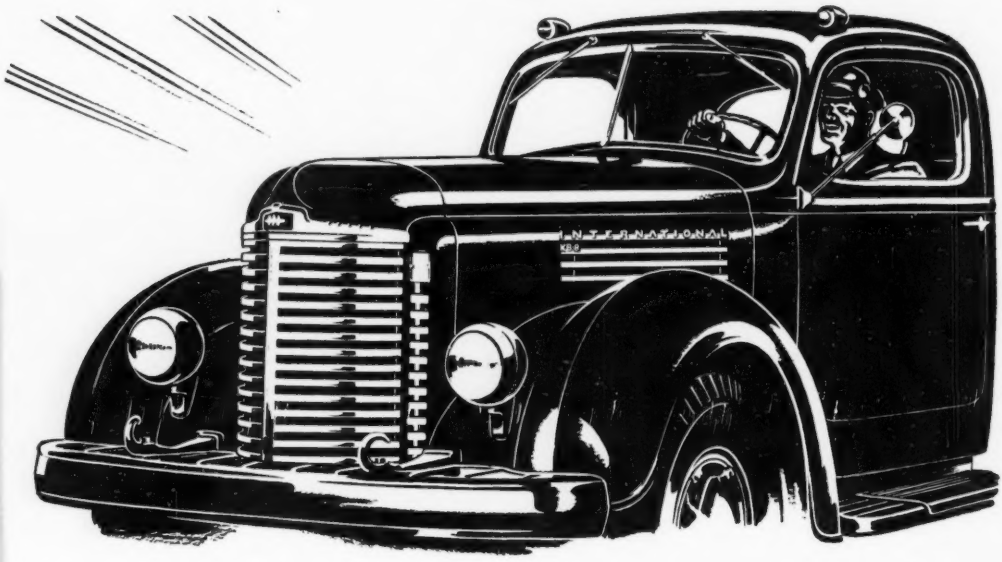
Hubbard and Company has pioneered an entirely New trend in flat steel crossarm brace production. Under the New procedure, all braces now have rounded ends. This New trend has achieved a three-fold purpose: easier handling, greater safety and neater appearance. Accidents involving lost time are reduced in number by the elimination of sharp corners. Hubbard Round End Crossarm Braces are preferred by the Linemen—the men who "Hang the Load on Hubbard Hardware."

HUBBARD AND COMPANY

PITTSBURGH CHICAGO OAKLAND, CALIF.

HANG THE LOAD ON HUBBARD HARDWARE

First in heavy-duty truck sales for 17 straight years!



America's most exacting truck buyers AGAIN give Internationals a vote of confidence!

Actual 1948 registration figures for new trucks of 16,001 pounds and greater GVW ratings show this nationwide preference for Internationals:

Internationals	**26.4%**
Truck "B"	**14.3%**
Truck "C"	**13.3%**

This marks the 17th successive year that Internationals have led in heavy-duty truck sales! Would men who buy on a basis of performance give a No. 1 rating to any truck unless it gave them a No. 1 value?

Outstanding value—right down the line! The same basic values that have kept Internationals first for 17 straight years in the heavy-duty field, are yours in any International Truck model. Heavy, light, or medium-duty, your International Truck is *all* truck. There's no compromise with passenger car design.

Trucks built to meet your requirements. Among the 22 basic International Truck models and 1,000 different truck combinations, there's a truck that's right for *your* job. In the range of gross weight ratings, from 4,400 to 90,000 pounds, you get the power, the frames, the axles you need for efficient hauling.

PLUS—the nation's largest exclusive truck service organization! 4,700 International Truck Dealers and 170 Company-owned Branches are ready with trained mechanics, precision-engineered replacement parts and low-cost rebuilt exchange units . . . ready to keep your International rolling at peak efficiency.

A truck transportation engineer is ready to help you! Call your nearest International Dealer or Branch, and find out how Internationals can step up the efficiency of your hauling. Trained International Truck transportation engineers will help you analyze your job—recommend a truck to lick it. If you're interested in profits, you'll call *soon!*

International Harvester Builds McCormick Farm Equipment . . . Farmall Tractors . . . Industrial Power Motor Trucks . . . Refrigerators and Freezers

Tune in James Melton and "Harvest of Stars," NBC, Sunday afternoons

INTERNATIONAL TRUCKS

INTERNATIONAL HARVESTER COMPANY • CHICAGO

ACCURATE TAPES

WORK BETTER
—because they're made better!

TAKE A GOOD LOOK AT THE TAPE YOU USE—

Every package of ACCURATE tape helps you produce better taped joints in less time. You know this as soon as you've stripped the first length off a new roll. The tape peels off straight and neat without ravelling —tapes up tight and even on the joint —and breaks clean right where you tear it. ACCURATE tapes work better because they're made by men who specialize in tape making.

PROTECTIVE PACKAGING

DIELECTRIC STRENGTH

HIGH TENSILE

EASY TEAR-OFF

NON-DETERIORATING

EASE OF APPLICATION

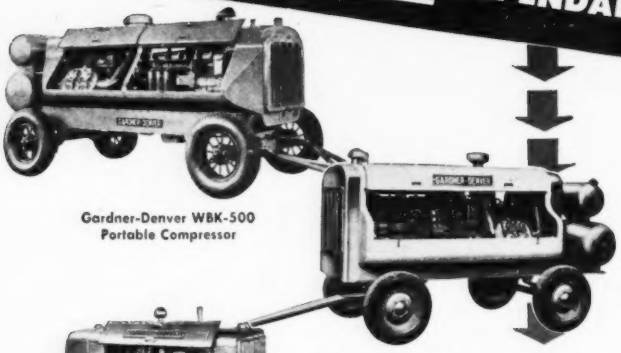
—if it's
ACCURATE TAPE
here's what you'll find!

First you'll see proper protective packaging. Substantial protective carton; heavy cellophane wrapper inside. Hold a length to a bright light—no pinholes anywhere. Then, when you use it, you'll notice ACCURATE tape never creeps or ravels and breaks off straight and neat. There's more than meets the eye, too. Every foot of ACCURATE tape is made to ASTM Standards and every roll contains guaranteed footage. That's why—when you buy ACCURATE tapes—you get real tape value. Next time you need tape—order ACCURATE. Write for catalog and name of distributor nearest you.

ACCURATE MFG. COMPANY
GARFIELD, NEW JERSEY

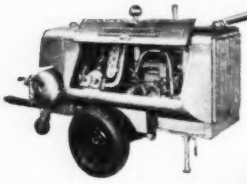
25 YEARS MAKING TAPES EXCLUSIVELY

AN ALWAYS DEPENDABLE AIR SUPPLY . . .



Gardner-Denver WBK-500 Portable Compressor

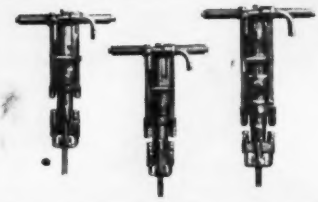
Gardner-Denver WHF-210 Portable Compressor



Gardner-Denver WHD-105 Portable Compressor

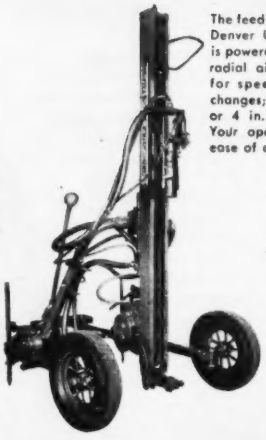
No matter where you send a Gardner-Denver Portable Compressor, you can be sure of a steady, uninterrupted air supply. For regardless of climate or altitude, the complete water jacketing of all cylinders "weather-conditions" them against over-heating — and from cold, unlubricated starts in sub-zero weather. For complete information, write Gardner-Denver Company, Quincy, Ill.

. . . FOR THE RIGHT AIR TOOLS



There's a Gardner-Denver Sinker that's "correct" in size and power for every type of ground. Shown here are the three most popular models: the high-speed S45 for secondary drilling or medium rock—the S55, most popular 55-pound sinker on the market—the S73, 67 pounds of speed and power for deep holes or the hardest formations.

Powerful Gardner-Denver B87 Paving Breaker has exclusive throttle safety latch — can be easily moved around the job without shutting off the air. Easily converted to a sheeting driver.



The feed of the new Gardner-Denver URM99 Wagon Drill is powered by a five-cylinder radial air motor. Designed for speedy, six-foot steel changes; carries a 3½ in. or 4 in. bore derrick drill. Your operator will like the ease of control.

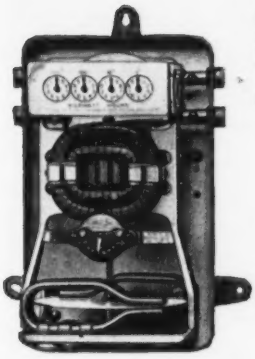
The Gardner-Denver T23 Backfill Tamper is balanced for easy "walking" over the fill — has valve and exhaust that won't "freeze" in cold, damp weather — contains integral oil reservoir that assures complete lubrication.

Gardner-Denver Model 28 Clay Digger makes digging easy in clay or hardpan—can also be equipped with axe blade for trimming or cutting timber, or with mail point or chisel for light demolition work.

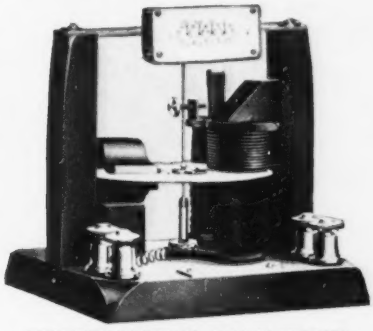
GARDNER-DENVER SINCE 1859

Milestones in

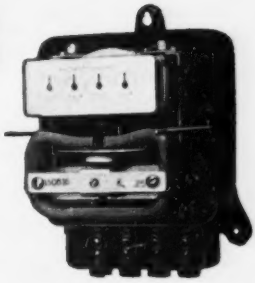
METER PROGRESS



TYPE E 1908-1940
TYPICAL OF ALL METERS
1902-1912

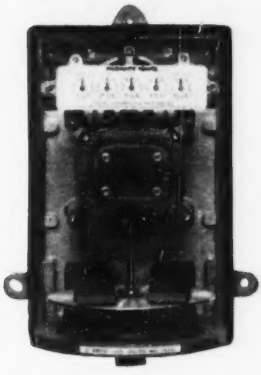


FIRST EXPERIMENTAL AC WATTHOUR
METER BUILT BY MR. DUNCAN
1892

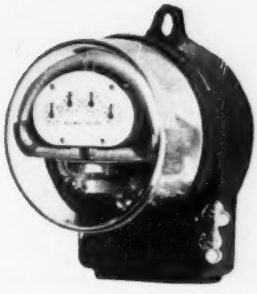


TYPE M AND MI
1913-1914

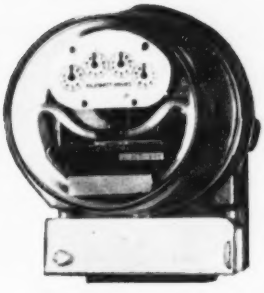
TYPE M2
1915-1926



FIRST TYPE OF METER BUILT AT
DUNCAN FACTORY, LAFAYETTE, IND.
TYPE A 1902



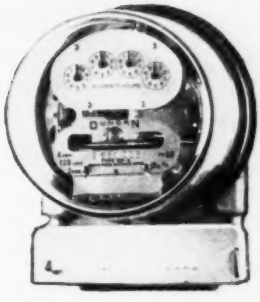
TYPE MD
1927-1933



TYPE MF
1934-1937

DUNCAN ELECTRIC MFG. CO.

Lafayette Indiana



TYPE MF ALNICO MAGNET
1938-—

DUNCAN

Makers of Watthour Meters Since 1902

POWERS line construction and maintenance bodies

Your workshop on wheels

On the rough, tough jobs miles from home a POWERS Body makes completion of the job easier. Built and designed to meet field requirements, all the necessary accessories, tools, supplies and equipment are ever-handy for instant use... for any problem. Sturdy, all-steel construction provides unwavering, dependable service year-in, year-out, through all kinds of weather, over all kinds of terrain. For complete information write...

ALL-STEEL POWERS PUBLIC UTILITY BODIES

McCABE POWERS AUTO BODY CO.

5900 N. BROADWAY • ST. LOUIS 15, MO.

OVER 75 YEARS EXPERIENCE

Now meter testing can be FASTER...SURER...SAFER!

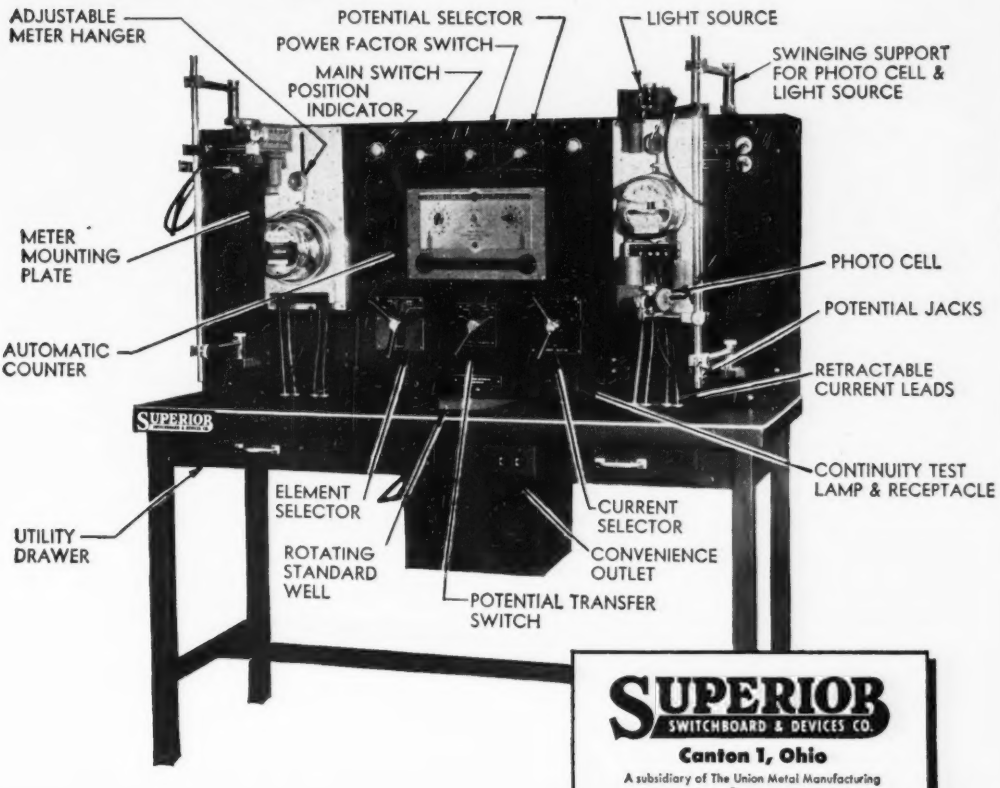
Superior's New

DUAL POSITION PHOTO-ELECTRIC TEST TABLE

Check These Features!

AS you can see, this rugged test table solves many a troublesome problem. It not only incorporates the most modern features helpful in accurate testing, but is designed to cut testing time to the bone while offering foolproof features for complete operator safety.

Superior now offers this modern, time-saving equipment as a standard, economical unit. But, as usual, we are prepared to make *any* type of testing equipment in accordance with your particular requirements and specifications. Your inquiries are always welcome.



SUPERIOR
SWITCHBOARD & DEVICES CO.
Canton 1, Ohio
A subsidiary of The Union Metal Manufacturing Company

SPECIALISTS IN QUALITY EQUIPMENT FOR METER TESTING AND INSTALLATION

Easily applied protection for lead-sheathed cable eliminates corrosion

Positive waterproofing and corrosion resistance

•

No elaborate cable cleaning necessary

•

Easy and clean to handle

•

Easily applied in narrow clearances

•

Uniform thickness insures smooth coverage

•

Easily stocked

● The application of NO-OX-ID Wrap, Dearborn's new protection for lead-sheathed cable, is as simple as unwinding a roll of tape. It slips through narrow openings with ease.

By combining two steps . . . the chemically protective coating *plus* a wrapper . . . application can be made by one man without special training or skill.

Just wind NO-OX-ID Wrap spirally around the cable, pulling it firmly to eliminate air pockets. Overlap it ½ inch. All cable area is protected against corrosion, all possibility of exposed surfaces from hand or brush application eliminated. A slight pressure of thumb and fingers on the Wrap insures a firm bond.

Supplied in 2-inch, 25-foot rolls, individually packaged.

For sample of NO-OX-ID, use the coupon below.

Dearborn
Reg. U. S. Pat. Off.
CHEMICAL COMPANY
Dept. EW2, 310 S. Michigan Ave., Chicago 4, Ill.
New York • Los Angeles • Toronto

Send for *this Sample*

Dearborn Chemical Company, Dept. EW2
310 S. Michigan Ave., Chicago 4, Illinois

Please send sample roll of NO-OX-ID Wrap.

Name _____ Company _____
Please Print

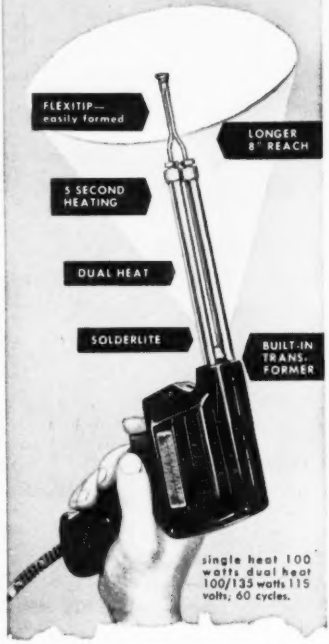
Address _____

City _____ Zone ____ State _____

which of these costly 6 HANDICAPS slows up *your* soldering?

Frequent Retinning and Redressing?
Delayed heating? Clumsy, rigid tip?
Obsolete source of heat?
Blind spots? Awkwardly shaped iron?

NEW WELLER *SOLDERING GUNS Eliminate Them All!*



Five-second heating saves time. Quickly formed FLEXITIPS slip easily between wiring. Prefocused Solderlite spotlights your work. And because heat comes "on" only when you pull the trigger, there's no over-heating—no unnecessary retinning or redressing with genuine Weller tips. Your Weller Gun pays for itself in a few months.

For all radio, television and appliance service work, use efficient 8" model DX-8 with dual heat, or 4" types—S-107 single heat or D-207 dual heat. Order from your distributor or write for bulletin direct.

Be sure to get your copy . . . SOLDERING TIPS, **the new Weller Handy Guide to easier, faster soldering — 20 pages fully illustrated. Price 10c at your distributor's, or order direct.**

WELLER
MANUFACTURING COMPANY
817 Packer Street • Easton, Pa.

"faster construction" it's a cinch with TULSA WINCH

This winch, especially designed for utilities, has extended drum shaft, detachable cathead, and adapter. Write for literature.

Jobs are handled with ease, more speed and positive assurance with a Tulsa Winch. Hoist, pull, lift and move all types of machinery and materials with a Tulsa Winch. Loads and men are safer because the automatic worm brake will hold the load at whatever point desired The favorite among Utilities and Contractors, each Tulsa Winch is built for longer life. Ask the man who uses one on the heavy, difficult jobs.

Tulsa Winch
TULSA, OKLAHOMA DIVISION OF VICKERS Inc.

WATER PUMP PLIERS
A slip-joint design permits four jaw adjustment... extra length handles give added leverage.
LINEMAN PLIERS with HANDLEGRIP
Powerfully built cutting pliers... shown with plastic insulating grips ... guaranteed shock protection against average voltage.
HEAVY DUTY COMBINATION PLIERS
A popular favorite with automotive mechanics, combining powerful cutters with tremendous gripping strength.
DIAGONAL CUTTERS
Finest diagonal cutter made... hand filed, perfectly matched cutter jaws. Recommended for cotter pins and tough cutting jobs.
NEEDLE NOSE PLIERS
Despite the slender nose they are extremely rugged. Specially machined for wobble-free action.

Vacuum Grip PLIERS

An Exclusive Snap-on Product

will far outlast ordinary brands!

1. Hammer forged from special high carbon Silco-Molybdenum alloy steel.
2. Hardened with liquid heat and oil tempered clear through—not surface hardening only. Joints locally tempered electrically.
3. Scientific design which distributes strain over entire tool assuring maximum strength.
4. Smooth, perfectly matched, easy riding precision machined joints.
5. Sharp, deep milled teeth giving intense gripping power.
6. Hand filed, perfectly aligned blades on all cutters.
7. Spring tempered Vacuum-Grip "Non-Slip" handles.

25 patterns. Available only through Snap-on's nationwide, direct-to-user tool service .... not at any hardware or mill supply stores.

Snap-on Tools
THE CHOICE OF BETTER MECHANICS

SNAP-ON TOOLS CORPORATION

8108-E 28th Avenue
Kenosha, Wisconsin

PORCELAIN ENAMEL SIGNS

MADE OF 18 GAUGE METAL

A complete line of Signs for every industrial need. Stock wordings for warnings, safe practice reminders and general plant notices.

SPECIAL SIGNS TO ORDER

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INDUSTRIAL PRODUCTS COMPANY

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NEW MODELS

NEW IMPROVEMENTS

NEW EASE OF INSTALLATION

The new Texanker models have improvements that are the result of extensive field experience and laboratory tests. Texankers are even better than before . . . easier to install and sturdily constructed with a minimum number of parts. They are well made with plenty of reserve strength for the years to come.

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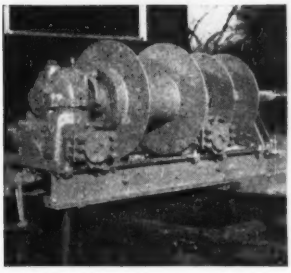
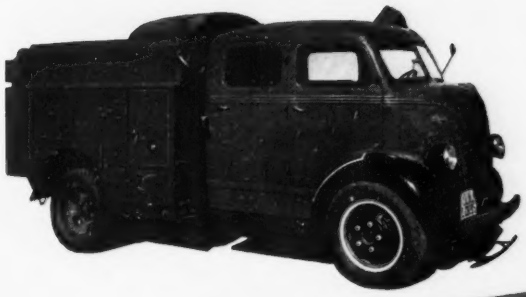
LUFKIN, TEXAS





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cuts costs, multiplies manpower, stands up under rugged conditions

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For 1½, 2, 3, and 4-ton trucks. Comfortable crew quarters. Plenty of organized space for all tools and materials. Perfectly balanced for proper weight distribution when loaded.

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Mounts on 1½-ton truck or light tractor. Needs only 6 square feet of platform space. In two minutes it can dig a hole 6" to 20" in diameter, 7' to 10' deep, at any angle, in clay, hardpan, shale, or frozen ground.

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Easy to load, easy to operate, easy to hook on behind any light truck. Saves time and manpower, simplifies transportation.

HIGHWAY POLE TRAILER

Permits entire load of poles to ride easily, economically behind maintenance truck. No need for special truck and bolster.

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Safe, powerful, dependable under all conditions. Capacity to fit any need. Models for all types of trucks.

WRITE for information on your special requirements. Highway Utility Equipment Engineers have the experience and the ability to give you the right answer promptly.

HIGHWAY TRAILER COMPANY

Manufacturers of: Utility Bodies • Winches • Earth Boring Machines • Pole and Cable Reel Trailers and other Public Utility Equipment.
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making sure with pounds not guesses...

Guesswork with high lines or guy wires is dangerous — unnecessary and most of all, costly. Summer slackness and winter tautness are unmerciful on your conductors — the "guess" method just isn't economical. Prevention of trouble is obtained only by strict adherence to the manufacturer's prescribed tensions for varying temperatures. Dillon Dynamometers were created specifically for this purpose. They are light-weight, portable and extremely accurate. Rugged — not injured by overload or hard knocks — shackle strength double Dynamometer capacity. Easy to use on pole or ground without cutting wire. Write today for your FREE copy of "Rules for Successful Wire Pre-Stretching and Stringing" — special bulletin on Dillon Dynamometer.

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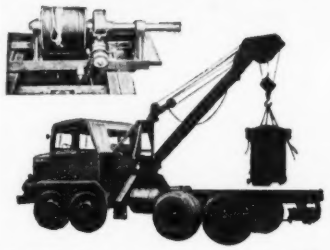
KRANE KAR Swing Boom Mobile Crane: for materials-handling . . . lifting, transporting, positioning, gasoline or Diesel, 1½, 2½, 5 and 10 ton capacities, 9 to 37 ft. booms (or telescopic booms), solid or pneumatic tires. Self-stabilizing without jacks or outriggers; unobstructed vision; fast, flexible, safe, easy to operate.



WINCHES: Capstans; Single and Double Drum, Jaw Clutch, Keyed and Friction Clutch Winches. 2,000 to 50,000 lb. Capacities.

SWING BOOM CRANES: Truck: Motor Power Operated; high capacity; takes up only a small space. For handling transformers, cable reels, lamp posts, trees, poles, manhole castings, etc. 9 to 31 ft. booms; one to 10 ton capacities.

TOWERS: 2 or 3 section type and Pantograph types, with plain, revolving or racking platforms.

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USERS: AT&T; N. Y. Tel. Co.; T.V.A.; Consolidated Edison Co.; W.U.; Municipalities throughout America.

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No. 79—KRANE KAR *No. 70—Truck Equipment*

THE ORIGINAL SWING BOOM MOBILE CRANE WITH FRONT-WHEEL DRIVE AND REAR-WHEEL STEER
2½, 5, AND 10 TON CAPACITIES
KRANE KAR
TRADE MARK REGISTERED
SILENT HOIST & CRANE CO.
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New LIGHTWEIGHT ELECTRIC PLANT

5000 WATTS D.C.

Weighs only 315 lbs.!

Model 5CK-115M, 5,000 watts, 115 volts D.C.

Use fast-working electrical tools on any construction or maintenance job with this high capacity, portable, compact electric plant. Equipped with four-receptacle box for direct plug-in of tools or lights. Available with carrying frame, or dolly-mounted. Powered by Onan 10 HP, two-cylinder, 4-cycle, air-cooled engine. Shipped complete . . . ready to go!

NEW ONAN "CK" ELECTRIC PLANTS are available in 5000 watts D.C., 115 and 230 volts; 2000 and 3000 watts A.C. in all standard voltages.
COMPLETE ELECTRIC PLANT LINE INCLUDES: A.C.—350 to 35,000 watts in all standard voltages and frequencies. D.C.—600 to 15,000 watts, 115 and 230 volts. Battery Chargers—500 to 6,000 watts, 6, 12, 24, 32 and 115 volts.
ONAN AIR-COOLED ENGINES—CK: 2-cylinder opposed, 10 HP. BH: 2-cylinder opposed, 5½ HP. 1B: 1-cylinder, 3¼ HP.

Onan PRODUCTS

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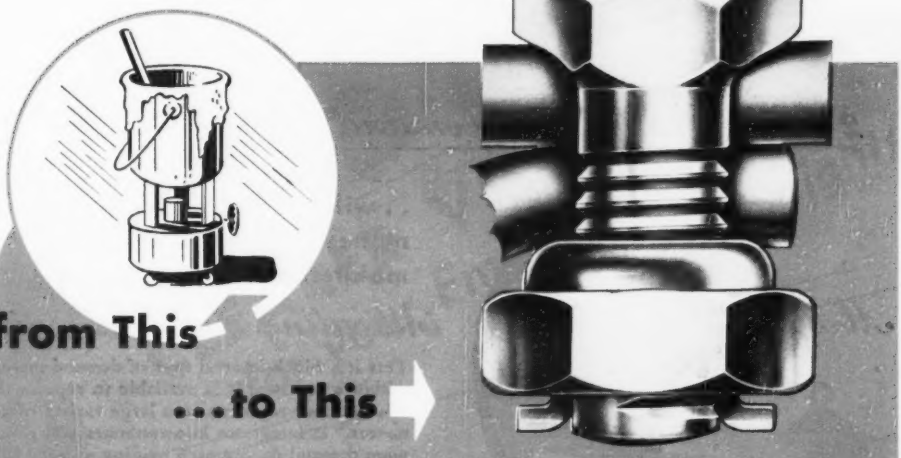
5431 Royalston Ave., Minneapolis 5, Minn.

ONAN ELECTRIC PLANTS

BEST WISHES TO ON YOUR 75TH YEAR OF SERVICE TO THE INDUSTRY



KEARNEY CON-NEC-TITES

23 Years of Improvement Built In

Since 1926 when Kearney introduced the solderless connector to the utility industry, Kearney engineers and research men have worked constantly to improve Kearney Con-Nec-Tites. And improve them they have, until today Kearney Con-Nec-Tites are known throughout the industry for their ability to withstand high torques, their high conductivity (80%), and ease of installing.

There are 75 Standard Kearney Con-Nec-Tites—in sizes from 1,000,000 CM to the small No. 10 . . . available for either iron, copper or aluminum conductors. Prices and quantity discounts sent on request.

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4224-42 Clayton Ave. • St. Louis 10, Mo.
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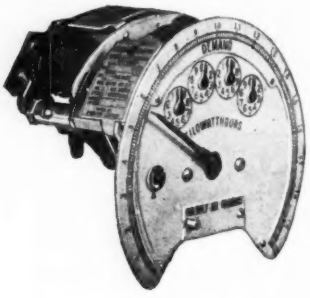
Always Specify JAMES R. KEARNEY CORPORATION ST. LOUIS, MO. *for the Job . . .*

Better Construction—SAFER Maintenance

General Electric Announces

2 New Simplified Demand Registers . .

. . will help you save money by decreasing maintenance costs



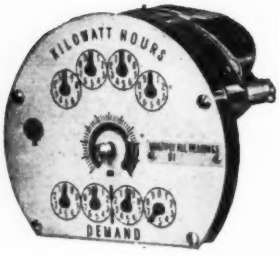
M-30 *indicating demand register*

This is a block-interval type of demand meter embodied within a register. It is available to replace the standard kilowatthour registers on a large variety of a-c watthour meters.* It integrates kilowatthours and gives the maximum demand during each reading period.

Your maintenance costs will be low because the timing motor, through a novel application of the Geneva mechanism, resets the pointer-pusher by direct-drive gearing, thereby eliminating the need for the spring and latch mechanism found in conventional demand registers. Internal resetting is accomplished with precision and freedom from shock.

Liberal spacing of plates, shafts, and gears gives maximum visibility for inspection. Very substantial plates, plus parallel arrangement of shafts, insure perfect alignment of parts and stability of bearings with minimum adjustments.

A wide, flat pointer with knife edge combines visibility and precision reading with minimum parallax.



M-31 *cumulative demand register*

This block-interval demand register (of the same basic construction as the M-30) indicates maximum demand during the reading period (usually one month) as well as the cumulated value of previous maximum demands. It has the advantage of leaving maximum demand for one period available for reference during the entire following reading period.

THESE REGISTERS lend themselves admirably to standardization and stock simplification. Also, you're assured of easier inspection and testing because of the fewer parts, interchangeable register timing motors (120- and 240-volt), and over-all simplification.

Let these features start saving money for you. Place an order with your nearest G-E representative today.

**Complete details on the M-30 in Bulletin GEC-413, M-31 in Bulletin GEC-272. Write for your copies now.*

Apparatus Dept., General Electric Co., Schenectady 5, N. Y.

GENERAL ELECTRIC

051-41

CLEARER VISIBILITY for your Emergency Crews on blackest nights

CARPENTER-LIGHTS
for Every Emergency

Carpenter's 33 years of experience in the lighting field has developed not only the largest but, we believe, by far the best line of portable, emergency and repair-crew lighting made. Superior design, top quality materials and the finest workmanship characterize all Carpenter-Lights and account for their unmatched popularity with public utilities, public works departments, businesses, industries and homes everywhere. Carpenter makes 67 types of worklights, searchlights, floodlights, warning lights, patrol lights and emergency lights for all conditions.

Type RA

A red flashing warning light for mounting on posts and on roof of emergency cars and equipment. All around visibility up to one mile. Built in flasher. Ruggedly built. Two sizes available.

Type RH

Portable flashing warning and danger signal for protection on highways. Red light visible a mile or more in any direction. Rust proof metal case. Housed-in flasher. Sturdy, compact, easy to carry. Uses Eveready Hotshot or Burgess Uniplex Battery and standard automobile tail light bulb.

TYPE "T & T" CARPENTER-LIGHT. Two-way light for line repairs. Searchlight beam for 10-foot circle at top of pole. 20-foot floodlight for inside and underground jobs. Uses 2 #6 dry cells. Most powerful and rugged made.

TYPE "T" ROOFMASTER. Roof Searchlight for Repair Cars, Buses, Trucks, etc. (Inside Pistol-Grip Control) Searchlight Range—one mile—Most powerful automobile spotlight made. Can be revolved in a complete circle, any angle, up or down. Ideal for locating and repairing breaks in overhead lines. Penetrates fog and smoke. Operates from car battery.

TYPE "WS". A lightweight, perfectly balanced hand light that gives an extra powerful (250,000 c.p.) concentrated searchlight beam. Penetrates smoke, fog, steam. Range one mile. Rechargeable, corrosion-proof, spill-proof battery. Other flood and beam portable types for emergency lighting in hospitals, banks, etc.

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MORE IMPORTANT *Today* THAN EVER BEFORE

CARPENTER MFG. CO.

167 Master-Light Bldg., Boston-45—Somerville, Mass.

Users Find that COFFING *Safety-Pull* HOISTS

—**MULTIPLY MANPOWER** Extremely easy to operate, they help workmen do more work, faster, easier. Ruggedly built to handle wider range of jobs.

—**COST LESS TO USE** Moderately priced, Coffing Ratchet-Lever Hoists have many parts of drop-forged, heat-treated alloy steel, other long-life features to hold down replacement and maintenance costs.

—**HELP RAISE SAFETY STANDARDS** Coffing safety features include dual ratchet and pawl assembly that cannot slip or drop load; "Safety-Load" handle to avoid dangerous overloading.

WRITE FOR BULLETIN E5SP, giving full information on nine models of the Safety-Pull hoist—$\frac{3}{4}$ to 15 tons capacity. See how they can help your workmen do *more* jobs—faster, easier, safer.

AMAZING HOIST-JACK IS A HOIST— A JACK—A PULLER

—3 useful tools in 1. Built in two sizes, 2000 lb. and 4000 lb. to handle scores of jobs. Send for Bul. E5HJ.

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ELECTRIC, SPUR-GEARED AND DIFFERENTIAL CHAIN HOISTS; "MIGHTY MIDGET" PULLERS; LOAD BINDERS

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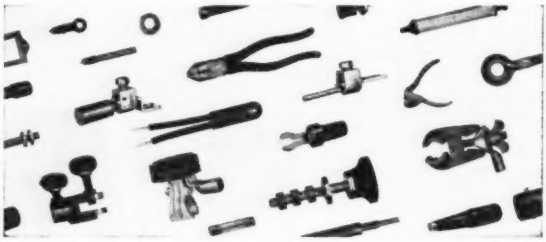

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MICHIGAN TRUCK CRANES SPEED LINE CONSTRUCTION

for Cleveland Electric Illuminating Company

Cleveland Electric Illuminating Company bought their first Michigan Truck Cranes in 1937—and they are still on the job. A new Model T-6-K 6-ton Michigan was added to their fleet this year and was instrumental in completing a 132,000-volt transmission line in record time.

Michigan's mobility widens the range of equipment operation throughout your system—excavating, unloading trucks, and setting steel. A Michigan Truck Crane goes to the job at 30 M.P.H., enabling your line crews to quickly cope with any emergencies.

Write for Bulletin 101 on the New Michigan Series 8 8-ton Crane—available with four-wheel drive and remote control.

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MICHIGAN POWER SHOVEL COMPANY

120 SECOND STREET • BENTON HARBOR, MICHIGAN

The 7-Range Clip-On Volt-Ammeter

FERRANTI

Offers These Important Advantages

- Measures up to 1000 amps—up to 600 volts.
- Convenient ONE HAND operation trigger action.
- Thumb operated range selector switch.
- 7 ranges—5 current and 2 voltage.
- Insulated core—shockproof construction.
- Takes cables up to 2¼" diameter.
- Distinct calibrations—easy to read.
- Suitable for 50-70 cycles.

RANGES: 0-10 amps; 0-25 amps; 0-100 amps; 0-250 amps; 0-1000 amps; 0-150 volts; 0-600 volts

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30 ROCKEFELLER PLAZA, NEW YORK 20, N. Y.
FERRANTI, LTD., Hollinwood, England — FERRANTI ELECTRIC, LTD., Toronto, Canada

Catalog Bulletins on Sherman Soldering Lugs available upon request.

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Battle Creek, Mich.

Sherman
SOLDERING LUGS

More Business and More Profits

An Editorial in ELECTRICAL WORLD
August 2, 1935

". . . We believe the electrical industry itself does not have adequate knowledge of the business outlook and of its opportunities for expansion. Exceeded quotas are looked upon as accidents and not as positive indicators. Executive attention, money and man-power are being used too casually. The industry is relaxed and rather content with the status quo, because red has turned to black on the books. It is not aggressive in its endeavors to expand sales, service and facilities. . . . And to the efforts of each electrical enterprise should be added joint action by all enterprises and all branches of the industry. . . . NEMA is in position to bring the initiative and leadership into action to awaken the industry to its opportunity and to help organize it for effective work. Why not act together for a common objective—more business and more profits?"

Heat Pump Also Presents Rate and Supply Problems

An Editorial in ELECTRICAL WORLD
October 25, 1947

". . . As a practical operation machine, the heat pump now exists. As a commercial proposition in respect simply to its own manufacture and sale, it is being born. As anything more than a mere novel application of electric service, it is still in the early stages of gestation. . . . The industry should not only be prepared to promote the heat pump, but be prepared as well to supply adequately to price equitably the electricity it will use."

Aiding Community Growth

An Editorial in ELECTRICAL WORLD
May 11, 1929

". . . Utility companies that advocate and actively promote industrial development in the communities they serve are doing something that should be a benefit to themselves as well as to the other members of the community. . . . It is good business and it is good public relations."

A Business Reason For Well-Paid Labor

An Editorial in ELECTRICAL WORLD
April 12, 1929

". . . Well-paid workmen expand the market for products and consequently are essential to a prosperous community and a prosperous country. The electrical industry in particular should recognize this principle, for its success depends to an unusual degree upon a prosperous community."

Who Belongs in Public Relations Department

An Editorial in ELECTRICAL WORLD
June 17, 1939

". . . Who is the public relations department of a company? One's first thought brings to mind the head of the department. An entirely different idea, however, was expressed recently at a McGraw-Hill Public Relations Forum by H. P. Liversidge, president of the Philadelphia Electric Company. He said: "I like to say in my own company that our public relations department is our largest department, because every one on our payroll belongs to it." This training cannot be done overnight. It is a continuous process. One must not let the size of the job get him down. Just make a start and keep it up."

Right About Face

An Editorial in ELECTRICAL WORLD
November 23, 1946

"It's about time the distribution engineers ceased "viewing with alarm" the loads that are assuredly imminent. It's about time they execute a right-about-face and start thinking of the distribution systems they should be aiming toward if they expect to be able to render the services likely to be expected by the users. They had better prepare their long-range budgets so that managements can do intelligent worrying about the money, the facilities and the returns. Otherwise the distribution engineer will forever be improvising and expanding with reluctance and restraint. If he does the right-about-face in attitude immediately he may someday be able to point with pride to his contribution."

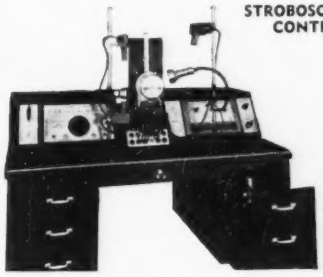
STATES TESTING EQUIPMENT

A Progress Report . . .

IN TESTING WATTHOUR METERS

Since 1911 THE STATES COMPANY has engineered and built quality testing equipment for watthour meter, relays and transformers.

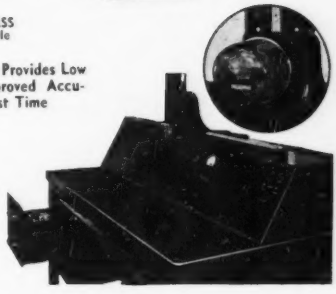
STROBOSCOPIC and PHOTO-ELECTRIC CONTROLLED METER TESTING



FORM FRSS Test Table

FORM FRSD Table

Automatic Control Provides Low Cost Testing. Improved Accuracy, Saving in Test Time



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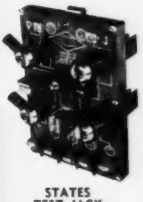
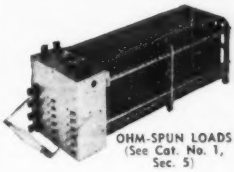


STATES TEST JACK For Type S Meters

—RELAY TESTING—



OHM-SPUN LOADS (See Cat. No. 1, Sec. 5)

Type RTS Switches for Relay circuits.

These push-pull type switches occupy a small panel space, may be obtained in equivalent of 2, 4, 6, 8, 10 double-throw switches, one hole mounting.

For Complete Report—send to

THE STATE'S LINE of Relay Test Equipment includes:—Noninductive Resistance Loads, Transformer Type Loads, Test Switches.

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TEL-E-LECT POLE HOLE DIGGER

- Digs a straight hole from any truck position
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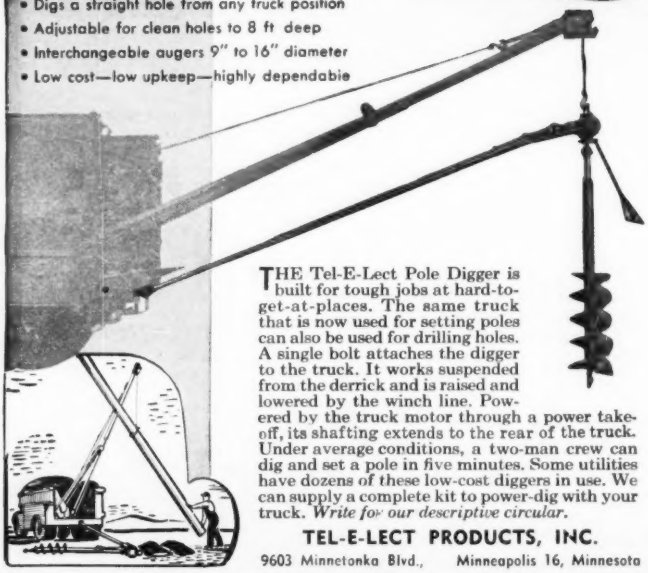
- Low cost—low upkeep—highly dependable



THE Tel-E-Lect Pole Digger is built for tough jobs at hard-to-get-at-places. The same truck that is now used for setting poles can also be used for drilling holes. A single bolt attaches the digger to the truck. It works suspended from the derrick and is raised and lowered by the winch line. Powered by the truck motor through a power take-off, its shafting extends to the rear of the truck. Under average conditions, a two-man crew can dig and set a pole in five minutes. Some utilities have dozens of these low-cost diggers in use. We can supply a complete kit to power-dig with your truck. *Write for our descriptive circular.*

TEL-E-LECT PRODUCTS, INC.

9603 Minnetonka Blvd., Minneapolis 16, Minnesota

F-11A

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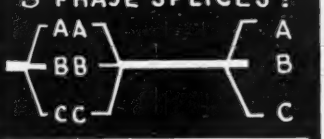
McGRAW-HILL PUBLICATIONS

3 PHASE SPLICES?



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Advantages:

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4. Saves up to 75% testing time.
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An extremely hard board of superior quality which can replace the more expensive types of insulating materials.

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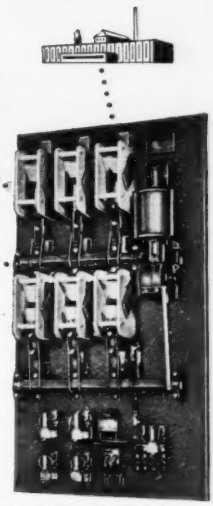

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EXPANSION IN USE OF ELECTRICITY

UTILIZATION OF ELECTRICITY
SALES PROMOTION
DEVELOPMENT OF RURAL ELECTRIFICATION

ORGANIZATION AND REGULATION

THE HOLDING COMPANY
DEVELOPMENT OF STATE REGULATION
DEVELOPMENTS IN RATE MAKING

EACH NECESSARY to the other, electricity supply and utilization grew up together. Invention and development of devices to use electricity required provision of energy for their operation, or availability of energy encouraged such invention and development.

The most clear-cut instance of this mutual dependence occurred in the earliest days of the industry. Edison's production of a practical incandescent lamp caused power stations to be built. But the stations stood idle in the daytime hours or ran under very light load. Here was opportunity for development of motors and heating devices to keep the power plants busy when light was not needed. In this fashion, basically simple, but so modified by the passing times and so overlaid with associated considerations as to appear very complex, did power supply and utilization progress together, each responding to the requirements of the other.

PUSH OUT
AND FOLD

But the invention and manufacture of utilization equipment had to be joined with another factor – selling – to provide an ever-widening outlet for electricity and electrical goods. Electric service and the devices to use it had to be sold. Thus sales promotion came into the picture.

By its nature, electric service had to be born and had to grow to maturity in the urban centers. It was slow to spread out to areas of low population density. It was just getting really started when the depression days came and put the quietus on expansion. Then the government stepped in and by its own action and by the spur thus administered so accelerated extension of lines over the countryside that today only a very small proportion of the population, farm, rural and urban, lives without the benefits and comforts of electricity.

Organization and Regulation

The devices by which this growing giant was controlled, expanded, made precise and subservient to the changing demands upon it varied considerably with the times and the state of the art. One of the most striking was the holding company, a device which, within a decade, was to be glorified and damned.

Two facts stand out clearly before those who examine the holding company. One is that it could hardly have been equalled as a means for developing the "small boy" lighting properties of 1920 into the "grown man" power systems of 1940. The other is that it provided an unparalleled legal mechanism for speculative abuse. Each of these salients was exploited thoroughly, with results that still condition performance.

Another device which shaped and continues to shape the growth and performance of the electric power industry is state regulation. It evolved from ineffective local regulation; saw broad variations in the criteria for ascertaining value; revised its concept as to the proper wages for credit. Many disparities remain in valuation, but a uniform system of accounting has evolved which is used everywhere.

Perhaps the most varied devices have been tried, adjusted, discarded and developed in the field of ratemaking. The ideal, thus far, has proved unattainable. But if the experts have been unable to work out a satisfactory "flat rate," they have, through all their experimentation, developed rates which have done the twin job upon which everything depended – sufficient revenues to let the business expand and low enough, yet fair enough, charges to make people want to use more and more of the industry's product.

Utilization of Electricity

In the three major fields of electric service, light, power and heat, utilization devices and appliances have multiplied in forms, types and sizes, but remain essentially the same as in the early days

ALL THE MEANS by which electricity is now used were known in principle long years before they found embodiment in the prototypes of the hundreds of kinds of utilization equipment that make electric service indispensable to modern civilization. This statement applies to fluorescent lighting, high frequency heating, and other new things of today as well as to motors, incandescent lamps, appliances, and many sorts of devices so long in common use. Anyone who takes the trouble to look up the antecedents of today's electrically operated equipment will find the origin in each case far back in history.

In 1924, when ELECTRICAL WORLD published its 50th anniversary issue, most of the appliances and equipments now in common use were already established as practical devices. What was accomplished in the past 25 years was their improvement and refinement and an ever-widening acceptance of them by the public. The tremendous growth in use is indicated by the accompanying charts.

The major uses of electricity today are the same as when the business of its supply began—light, power and heat. There are other uses; some were in practical application from the beginning of the industry, such as electro-plating and electrolytic reactions, and others were of later development, as in the perceptive and control functions of electronics. This review of the development of utilization devices will be mostly devoted to the three major uses.

More and More Light

The incandescent lamp is a beautiful example of the truism that the solution of a problem is merely a step towards more problems. No sooner had Edison produced a practical lamp than he and many others began to see things wrong with it and to look for ways to cure them. At first the incandescent lamp was very inefficient. Its carbon filament produced only 1.41 lpw. To date its efficiency has been multiplied ten times to a mean 14.1, with large size and special lamps producing 30 or more lpw.

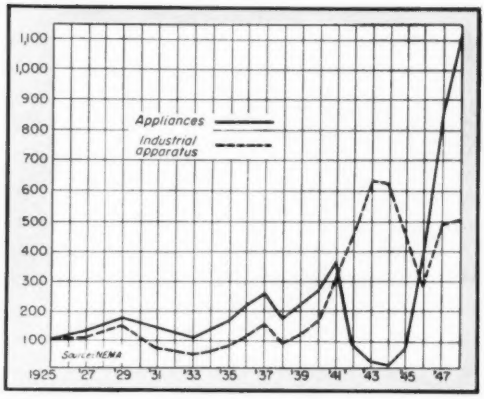
The first lamp in general use was rated at 16 cp, its power requirement about 60 w. From this small beginning has grown today's lamp production of over 1¾ billion units sold in 1948 in thousands of shapes and sizes from the smallest "grain of wheat" lamp rated at 0.17 w to the giant of 50 kw. The reason for this tremendous growth is easily found. Taking into account decreases in prices of lamps and of electricity and the increase in light production efficiency, the user today pays only one 5,000th as much for incandescent lighting as he did half a century ago.

It is generally considered that the arc lamp is a back number. It was for a time. Slimmed down to modern lines, so changed as to be almost unrecognizable, it came back on the stage in 1938 and has held the spotlight ever since. But it is the same old arc lamp as ever was, even though its name now is fluorescent.

Arc Lamp Redivivus

It had long been known that certain materials could be caused to fluoresce, to glow and emit light, when excited by short-wave radiation of energy. Edison filed a patent application on a fluorescent lamp in 1896. But it took over 40 years for the idea to come to fruition. And when it did it transformed the lighting art almost overnight. Light production efficiency was more than doubled. The low brightness of the "line" source of the fluorescent tube as compared with the much higher intensity of the "point" source of the incandescent lamp required the development of new methods of light application. The greater efficiency of the tube, its lower operating temperature, and its flexibility of adaptation to architectural design made possible the use of far greater amounts of light than before. Now just out of its first decade, the fluorescent tube has already undergone many changes and improvements. It is available in almost any desired shape and size. Indicative of the rapid growth of fluorescent lighting is the record of 86,000,000 units sold in 1948.

The theoretical perfect efficiency of light production is some 220 lpw. This is "cold" light, the complete transformation of electricity into light. On this scale, fluorescent lighting is about 30% efficient, incandescent under 15%. Since heat is a necessary step in the transformation of electricty into light by incandescence, it seems that the attainment of perfect efficiency is denied to the incandescent lamp. In the very nature of things, the possibility of perfect efficiency is denied to the fluorescent tube also, but certainly it



SINCE 1925, annual sales of electric appliances have multiplied over 11 times and of industrial apparatus over 5 times

has a much greater potentiality of efficiency increase than the incandescent. New and revolutionary methods of light production now may be gestating in research laboratories, but so far as general knowledge goes, the immediate future of large improvement belongs to the fluorescent tube.

Different from lighting, the history of electricity as a motive force contains no outstanding developments that changed the whole aspect of application. It might be argued that the work of Tesla and others in the invention and development of the alternating current motor should be so classified. But the basic phenomenon of the motor, electro-magnetism, is the same now as when Thomas Davenport appropriated his wife's best dress to use the silk as insulation in the first commercially successful motor in 1837. For a really revolutionary change in the electric motor, we must wait for the successful results—if they ever come—of present research towards replacement of the electromagnetic by the electrostatic field in motor design.

Motor Speed Problem

The alternating-current motor is inherently a constant-speed machine. It is a stiff-necked performer, wanting always to run at synchronous speed or as close thereto as it possibly can. Although many patents have been issued on ways to change its speed as desired, none have had more than rather special application. The direct-current motor, however, is more obliging. It can easily be designed to respond amiably to comparatively simple means for speed changing. This characteristic difference between the two motors has kept the direct-current machine in quite wide use although alternating current has superseded direct as the commercial supply except in comparatively small downtown areas of the largest cities.

The speed flexibility of the direct current motor is most largely responsible for the development of equipment for converting alternating to direct current. The first of these was the Westinghouse rotary converter in 1892. Ten years later came Cooper Hewitt's mercury arc rectifier. In its modern form this rectifier now pretty well dominates the power field. Recently a challenger has risen, a form of mechanical or "contact" rectifier, which employs the magnetic characteristics of a newly-developed alloy. How successful this new device will be remains for the future to say.

Motors in Household Use

The important thing about the motor load is the rapid spread of motor applications to uses undreamed of in early days. Anyone then predicting that an ordinary American home would contain from 10 to 40 motors would have been laughed out of court. In those days the motor was merely a substitute for an engine or a horse. Today it is found everywhere. *Electrical Merchandising* lists 18 motor-driven devices in its report of appliance sales in 1948. Only one of these, the fan, was in existence at the turn of the century. Most common motor application in the home is the electric clock; 10.5 million were sold in 1948. Next comes the refrigerator with a sale of 4.5 million. And in industry everyone knows that the electric motor has been the principal contributor to this country's pre-eminence in production.

The third, and probably the largest in potential, of the major uses of electricity is heating. The real start for electric heating devices came in 1906 when A. L. Marsh patented a nickel-chromium alloy for use as a heating resistor. Although George A. Hughes is known—and rightly—as the father of the electric range, his accomplishment was the commercial pioneering of electric cooking, following his demonstration of a practical range at the 1910 convention of the National Electric Light Association.

Flat Iron Still Leads

But it was not the cooking range that got power company managements generally enthusiastic about the heating load. It was the electric flatiron introduced at the Chicago World's Fair in 1893. Real promotion of the iron began about 1905. Power companies gave them to customers in large quantities to get them into use. After the iron, development of other heating devices followed rapidly.

To review here the history of electric heating appliances from the early days to the present is impossible. An idea of the tremendous development in the less than half century since the flatiron was first promoted can be had from *Electrical Merchandising*'s listing of domestic heating appliance sales in 1948. The list contains 18 entries of appliances using electric heat. The list is not inclusive by any means. The 18 entries total 25,470,000 units sold, their retail value amounting to $947,302,000. It is interesting to note in the list that the flatiron still leads all other heating appliances in number sold; it accounts for over 25% of the total units.

Electric heat is applied in industry in 4 distinct ways: By the arc, by resistance, by induction and by the electrostatic field. These ways are employed for many purposes—metal melting, annealing and case hardening; infrared drying of surfaces and curing of

finishes; brazing; welding; and in a great diversity of process operations such as curing rubber, bonding plywoods, pre-conditioning materials, preparing plastic preforms, maintaining flow of heavy liquids in pipes, etc. An idea of the growth of these applications is presented in the accompanying chart of electric furnace steel production. An inclusive total of electricity consumptions for industrial heating is impossible of compilation, but one could venture a guess that a third or more of the 124 million kwhr used in 1948 by large light and power customers of electric utilities was used for this purpose.

Informed opinion is that electric heat in industrial applications still has far to go before its potentialities are exhausted. Last year F. R. Benedict, Westinghouse, estimated that the market for resistance welding and electric brazing equipment was 3 times the amount in use; that continuous strip annealing of steel could require 1 million kw very quickly; that infrared heating could grow by steps of 200,000 kw annually for the next decade; that electric furnace steel melting had a yearly increment possibility of 500,000 kw, resistance furnace heat treating, 50,000 kw, and high frequency induction and dielectric heating 10,000 kw.

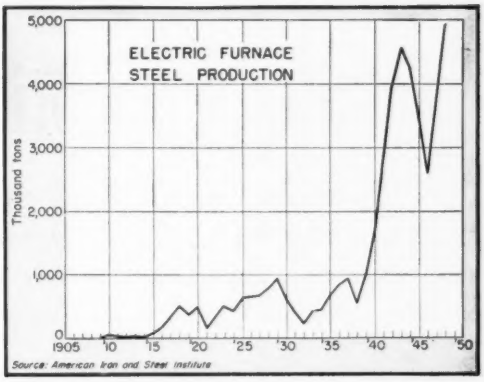
Tomorrow—House Heating

These industrial potentials are overshadowed by another electric heating development, not so immediate, but which farseeing utility management is now taking into account. This is house heating. It is already an important consideration in some parts of the country, although not yet a significant component in the national picture. Some studies of its load characteristics have been made, enough to show that much more work must be done to assure its proper application and to provide suitable rates and adequate service facilities for it. Also it remains to be seen what form of electric house heating will ultimately predominate. The convection method is limited by the heat content of the kwhr; radiation somewhat reduces that disability; the heat pump is left as the most attractive possibility.

Parallel with the expansion of the three major uses of electricity, have been the developments in the past quarter century in electro-chemistry and electronics.

In metal and chemical productions electrolysis now find large application. It is used in the reduction of aluminum and other light metals from ores and salts and in the refining of other metals such as copper, zinc and nickel. End products of chemical processes in which electrolysis figures include synthetic fibres, dyes, solvents, refrigerants and numerous others. Here again, as in motive power, the basic phenomenon—electro-deposition—is the same as when the early experimenters made electroplating baths. The development has been in expansion of applications and in improvement of their methods. The mercury-arc rectifier greatly accelerated the development of electrolysis as an industrial process.

Some idea of the extent of electricity use in this field is afforded by the increase in energy requirements of electrolysis in aluminum reduction and copper refining. In 1908, 5,340 tons of aluminum were produced, using some 160,000,000 kwhr. In 1943, at its war peak, aluminum production was 920,000 tons, using over 18 billion kwhr for electrolysis. In 1948 the energy requirement was around 12 billion kwhr. Contrasted with the approximate 10 kwhr per lb for aluminum reduction, the refining of copper is a much smaller user of electricity, something like 0.15 kwhr per lb. On this basis about 360 million kwhr were used for the 1948 production of around 1,200,000 tons of electrolytic copper. On these sparse data one might guess that about 5% of the 1948 electric utility output was used in electro-chemical processes.



NEARLY 5 MILLION TONS of steel were produced in electric furnaces in 1948, an increase of 500-fold or more in 40 years

Electronic Applications Surge Ahead

Largest use of electricity in electronic applications is in radio reception. Receiver saturation in this country is about 95%; nearly 38 million homes have them. The number of receivers in use is far higher; 16 million were sold in 1948, probably there are around 75 million in use. Now comes television, with something over 1,000,000 receivers now in use. Estimates of future sales indicate the probable installation of 15 million sets in the next 5 years. At a net increase in domestic energy consumption of 250 kwhr per receiver per year, this represents the annual sale of nearly 4 billion kwhr. In industrial and power supply apparatus electronic applications are multifarious. They figure in rectification, in dielectric and high-frequency induction heating, and in numerous perceptive and control functions, too many to catalogue here.

Invention and development of utilization equipment determined the growth of electric service during the past 75 years. They will not stop now. New things and improvements of old ones will keep on appearing, continually enlarging the usefulness of electric light, power, heat and other applications. The pioneers of electric service had no past to look back on and to take lessons from. That they did so well, out of ignorance, is a challenge to present-day utility men to do better, out of knowledge.

Sales Promotion

Power supply business was 25 years old before the need for broad-front selling became apparent. At first, and for a long time, most of the initiative for industry-wide promotion came from manufacturers, but recent utility activities indicate a change

"Our earnings through economy of operation have well-defined limits, but the possibilities of increasing our earnings by developing our market have a much wider range."

These words might have been uttered by some utility sales executive at the EEI commercial section meeting in Chicago last month. But, applicable as they are to present-day conditions, they were not. Henry L. Doherty, an outstandingly sales-minded power company operator, spoke them at the 25th convention of the National Electric Light Association in 1902, nearly 50 years ago.

A parallel thought had been expressed five years earlier when T. Commerford Martin, whose name is a distinguished one on the roster of past editors of Electrical World, said to the 20th NELA convention that, "the companies restrict themselves injuriously in their natural and logical advance by remaining mere lighting corporations." He then went on to point out the possibilities of business increase in the motor and heating loads, and presented what is probably the first report to the industry on electric cooking.

Beginning to See Opportunities

As its development appears in the records of NELA, the power supply industry was beginning in the decade 1895-1905, to appreciate the opportunities for new business that lay before it. Committees to study sales potentialities and problems were formed and reported regularly. The 1906 convention featured a symposium on "Some Methods of Securing and Retaining Business." A year earlier marked the start of a new idea for sales promotion, setting a pattern that produced great results then and still does. It was the idea of co-operation between makers of electricity-using devices and suppliers of electricity.

Speaking for the makers of lamps, J. Robert Crouse presented to the 28th NELA convention, 1905, a co-operative plan for business promotion for which his backers had authorized a first-year expenditure of $10,000. When Mr. Crouse reported on the plan at the next convention its working fund had increased to $60,000 for 3 years and it had been organized as the Co-operative Electrical Development Association.

The NELA record contains little or no information on the activities and accomplishments of the Co-operative Electrical Development Association. One must assume, however, that it was active and did get results in its enthusiastic first years, at any rate. It was in these years that commercial matters were accorded the recognition of a definite section in the NELA convention program. The first time was in 1907 when a series of some 30 or more papers and reports were presented on sales policy, selection and training of salesmen, advertising, wiring, and techniques of selling light, power and heating. Included in these programs were statements from industry publications, for instance, here is a quotation from Electrical World at the time, "In articles and editorials the Electrical World has striven to direct the attention of central station men to new lines of profitable business in the sale of current, such as electrical refrigeration, automobile charging, solicitation of small residence lighting, introduction of electric cooking and heating, etc. . . . The illustrations are largely of advertising matter, bulletin covers, posters, billboards, signs, and methods of . . . keeping track of new business and prospects."

It would seem from this recital that salesmindedness had by 1910 become an integral part of management consciousness. But at that time, there were those who took the opposite view. In that year Arthur S. Huey said, "The central station industry has suffered too long from lack of the genuine commercial spirit. . . . Instead of the judicious cultivation of the use of electrical energy by the public, too many operating companies have contented themselves with simply offering service and letting it go at that."

First Electrical League

In 1908, Mr. Crouse, moving spirit in the Co-operative Electrical Development Association, organized a local group for industry promotion in Cleveland, Ohio. This was the first of the many electrical leagues that now forward the interests of electrical retailers, contractors, jobbers, manufacturers and utilities all over the country.

For his indefatigable work in bringing together in common effort the different branches of the industry, Mr. Crouse was the first recipient of the McGraw Award for co-operation. This award, with three others for distinguished service to the industry, was established in 1925 by James H. McGraw, publisher of

ELECTRICAL WORLD and other business magazines.

By 1913 it was felt by many in the industry that co-operative promotion needed rejuvenation and the Society for Electrical Development was organized. The Society began operation the next year with a slogan, "Do It Electrically," a working fund of $200,000, and a membership of 279 central stations, 173 manufacturers, 568 contractors, 262 jobbers, and 18 miscellaneous. In addition to its continuing promotional work, the Society sponsored numerous special campaigns in the following few years. Some of them were: "Electrical Prosperity Week," 1915; "Wire Your Home Month," 1916, again in 1917; "America's Electrical Week, 1916; "Industrial Lighting Campaign," 1920, again in 1926 and 1927.

In Toronto, Canada, in 1923 the manager of the local electrical league, Geo. W. Austen, had a brilliant idea. It was the "Red Seal," certification of home wiring as meeting a specified standard of adequacy. This idea was adopted by SED and promoted vigorously; at one time over 50 local leagues were carrying on active campaigns.

The Red Seal promotion was the last major activity of the SED. By 1926 it had become practically moribund although it remained in existence until 1933. As SED declined another co-operative organization rose up. This was the Joint Committee for Business Development in which some 12 industry associations participated. There is little in the record about the activities of this group and one assumes that it did not live long.

But Promotion Continues

In the meantime, however, nation-wide promotion kept going. There was the "National Home Lighting Contest" in 1924 in which a $15,000 home was the first prize. An advertising campaign costing $300,000 publicized the contest. It had been estimated that entries would be received from at most 1500 communities. Actually 4,774 cities and towns were represented by contestants. Co-ordinated promotional activities, by which manufacturers and utilities synchronized their selling efforts on specific appliances, brought satisfying results in this decade. Utility sales managers were spurred to special effort in 1928 by a "Kwhr" contest, prizes given for largest increases in average annual residential sales.

In the early 'twenties the domestic electric refrigerator appeared on the market. At first expensive, clumsy and with quite a few "bugs" in it, it developed rapidly and in a few years had gained wide acceptance. Its first co-operative promotion was by the National Food Preservation Council, "50 Degrees the Danger Point," in 1929. The Council was followed by the Electric Refrigeration Bureau which dissolved in 1934, its work done with the refrigerator securely established in public acceptance.

With the demise of SED in 1933 came the end of any idea of centering all promotional effort of the industry in a single agency. Since, then, promotion, co-operative or otherwise, has been carried on in each instance by the interest or interests immediately concerned. Conspicuous among these are the National Better Light-Better Sight Bureau and the National Adequate Wiring Bureau, both in active operation today. Among other activities started in the 'thirties, some fallen by the wayside, others still active or with successors in the same grooves, are the National Electric Cookery Council, Electric Housewares Program, Electric Water Systems Council, Modern Kitchen Bureau and Commercial Electric Cooking Council.

Since the war, industry promotion of electrical goods and services seems to have settled definitely into a form whose shape was evolving in the late 'thirties. Gone is the idea of pooling funds from utilities and manufacturers. Instead, each interest recognizes its specific responsibilities and discharges them. Two activities now in operation, the Planned Lighting and the Electric Kitchen programs, are good examples. For these the utilities set up their own organizations to sell the ideas of modern lighting and modern kitchens at the consumer level, leaving to the manufacturers the job of selling the indicated electrical goods at the trade level. Co-operation of the two interests and co-ordination of their efforts are essential and are not lacking.

Present Sales Activities

Among the promotional activities now being carried on by groups of manufacturers are traffic safety lighting, water heating, domestic and commercial cooking, farm and home freezers, and farm electrification. Each of these finds supporting activity in the sales operations of individual utilities, if not in organized programs of the utilities together. Additional to the group activities of manufacturers are the General Electric "More Power To America" and the Westinghouse "Productive Power" programs, both dedicated to greater use of electricity in industrial operations.

Although statements, like those of Mr. Doherty in 1902 and of Mr. Huey in 1910, have been made many times since and are still heard occasionally, it is apparent that salesmindedness now prevails in power company management more widely than ever before. As yet, however, sales activities of individual companies have not generally returned to immediate pre-war levels in terms of manpower employed and of scope and intensity of promotion. The reason has been the unprecedented growth, instead of the anticipated decline, of load following the war. The reason is now evaporating as capacity additions accumulate.

The necessity for earning returns attractive to investors on the high cost capacity now being added is putting a heavier imperative on selling than the industry has previously known. It is emphasizing that selling effort must be selective, must be directed towards those loads of largest potential earning power. This requirement includes enlarged and more specific knowledge of load characteristics so that informed selection can be made of directions for sales effort to take. It includes also close control and supervision of sales operations and highly trained sales personnel. These requisites point towards better organized and more effective sales promotion in the near future than the history of the industry can show.

Rural Electrification

Time was required for electric service to spread out from urban centers to rural areas. As job approaches completion, problem becomes increasingly one of promotion of electricity uses

FARMS CONNECTED to electric lines in this country numbered 4,388,200 at the end of 1948. Of these, 2,250,595, 51.3%, are served by power companies; 1,921,160, 43.7%, by REA co-operatives, and the remainder, 216,445, 5%, by municipal and other government agencies. These are figures published by the Edison Electric Institute.

It is impossible to state accurately what proportion of farms receive electric service today. The last official figure on farms is that of the U. S. Census of Agriculture for 1945, 5,859,169. On this basis, 75% of U. S. farms now have electric service. For 1947, the Edison Electric Institute said that 750,000 farms were close enough to power lines that they could be connected if they wished and they should be counted as having service available. This statement was and is disputed by REA spokesmen. But any fair-minded person must admit that it is at least partly true. Therefore it is safe to say that the job of bringing electricity to U. S. farms is at least 75%, possibly 85% or more, complete.

REA was started in 1935, but the EEI data show no co-operative consumers connected that year. There were a few probably, but the REA did not really get going until 1936. At the end of that year, 1,042,900 farms had service, 6,550 of them from co-operatives.

Off to a Slow Start

The record on farm service goes back to 1898, but it remained a definitely fringe activity through the next 20 to 25 years. Their work of making electricity available to the urban population then well in hand, the power companies began giving real attention to the problem of service to the thinner rural field. A convenient benchmark for the beginning of industry-wide concern with farm electrification is the year 1923. It was then that power companies, manufacturers, farm organizations and others interested got together to form the Committee on Relation of Electricity to Agriculture—of which more later. At that time fewer than 200,000 farms had service.

From 1923 to 1930, when the depression days began, the power companies built farm lines at a rate that, if continued, would have resulted in service to every farm in the nation by 1941. But the depression was a powerful brake and largely because of it REA came into existence. REA loosed the brake. Result was that the rate of growth of farm connections for the 5 years 1935-1940 was practically the same as it had been in the period 1925-1930, before the depression had flattened the curve. The war flattened the curve again, but it picked up immediately afterward and is now back to about the same slope it had twice before.

Profit to Farmers, the Essential

Number of farms connected, however, is not by any means a complete index of farm electrification. It is only one part of the index and, in terms of national well-being as opposed to politics, it is the less important part. The important thing is employment of electricity to increase farm production. This was an early idea in the minds of power company men. They saw that for farm service to pay its cost the farmer must use plenty of electricity. To that end they must prove to the farmer that large use of electricity would be profitable to him. From this thinking resulted the Committee on Relation to Agriculture, before mentioned.

The purposes of CREA were to serve as a national clearing house for farm electrification data and information, to sponsor and encourage research into development of new and improvement of existing farm electric uses, and generally to strive towards enlargement of farm service and reduction of its cost. Local CREA's were established in 27 states, some of which continue in active operation in one form or another, although the national committee was dissolved in the '30's. Test projects were set up in seven states, with utilities, manufacturers, and educational and research agencies cooperating. The first and best known of these was the Red Wing project in Minnesota which was carried on for five years. Appliances and equipment were loaned by 79 manufacturers. The total cost of the test approached $100,000. Capping the state tests was the National Rural Electric Project in Maryland started in 1928 and continuing for five years. The records of these projects and of other CREA activities remain today as a comprehensive and authoritative source of information on productive

applications of electricity to farm uses.

Despite the chart lines of trends earlier remarked in this article, REA accelerated tremendously the spread of farm service lines over the nation. It did this by its own work in the organization of electric co-operatives and by the spur it gave to the power companies. REA got off to a bad start. It was conceived in hate of the "Power Trust" bogey that, on the politician's call, still arises, albeit somewhat creakily, from the sulphurous depths. It is unfortunate that today, after nearly 15 years, a considerable residue of that animosity remains in the farm service picture.

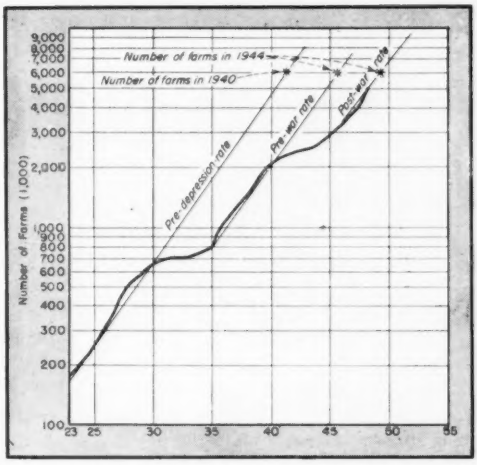
REA set out to prove that the power company approach to rural electrification was entirely wrong. It saw rural electrification simply as a job of connecting to power lines as many farmers as possible in as short a time as possible and as cheaply as possible. The height of this folly was reached in the production to REA requirements of 600-va transformers, it being seriously advanced that units of such small size would be ample for most farm connections.

Be it said to REA's credit that such mistaken ideas belong to the past and that today its engineering philosophy recognizes the realities of electricity distribution and utilization. There are evidences that as co-operatives accumulate experience in the business of power supply, it can be said some time in the future that the feeling of animosity also belongs to the past, in spite of strenuous efforts of some men to keep it alive.

Agricultural Revolution Now Beginning

A parallel can be seen between the industrial revolution of the 18th and 19th centuries and what has been developing in agriculture in recent generations. As better machines came along, better powered and controlled, the industrial revolution speeded up. This is occurring in agriculture in our day. It actually has gone much farther than is generally realized. It has been estimated that half of the national cash income of farmers goes to 10% of them. About 80% of the cash income goes to 30% of the farmers. Income is received for products sold. Products sold are what feed and clothe the rest of the population. The division of income says that up to three quarters of the nation's farms contribute little or nothing to agricultural production. This is not to infer that the people living on these farms are all lazy drones. They may be doing useful work on other farms or in other lines of endeavor. The point is that the modern farm tends more and more to become a factory producing food and fibre, the same as the Lancashire weaver's cottage turned into a cotton mill.

This agricultural revolution has already been much affected by rural electrification and will be increasingly affected. Completing the turn, it affects electrification. Looking ahead and considering other factors such as transportation and communication which tend to increase rural population, one can perhaps discern the shape of farm service in the future. It appears as service to farm factories scattered about the country side and to homes interspersed between. The problem



RURAL ELECTRIFICATION growth returns to about the same trend line after interruptions of depression and war

becomes one of supplying adequate service to, and of obtaining adequate revenue from, widely dispersed users of electricity, most of them in the residential customer class.

Compared with the exact techniques, with the precision machines, with the organized work methods of industry, agricultural production still has far to go. But one can see that it may go far in a short time with the help of electricity. One needs only to reflect on the promises of "farm chemurgy," on the rapid advances in refrigeration and freezing of foods, on discoveries in animal and plant biology, on methods of soil utilization and care, on the increasing practicability of food and other processing in comparatively small units of production—one has only to think of these and like developments to see the immense potential of electric service to rural areas.

All Together for Progress

Working towards realization of this potential is a large army of men and women. They are working in the experiment stations of the U. S. Department of Agriculture and in the agricultural schools of colleges and universities. They are working in research and experimentation sponsored by government, by power companies, and by manufacturers. They are working as county agents, as farm service advisers of utilities, and as REA and co-operative personnel. They are working also in local, regional and national organizaitons such as the National Grange, Farm Bureau Federation, National Farm Electrification Conference, and in youth groups like the 4-H Clubs, Future Farmers of America, and Future Homemakers of America. Their efforts appear in the rapidly rising average annual usage of electricity—excluding irrigation—on the farms of the nation, that has trebled in 20 years, rising from 670 kwhr in 1928 to 1997 in 1948. And the rate of increase is accelerating.

The Holding Company

Public utility holding companies have been in disrepute for years, but they built the bridge by which the electric power industry made the crossing from small, ineffective local companies to an industry which helped win a war

THE ELECTRIC UTILITY industry is 67 years old and going stronger than ever. But the public utility holding company, which is almost as old, enjoys far less expansive a future.

It isn't as if the holding company is completely done for. Stringently as Congress dealt with public utility holding companies in 1935, it by no means ruled them out of existence—it refused flatly, in fact, to do just that—for the device was entirely too valuable to be discarded. But the vast changes it demanded of the holding company structures then in existence, and the new rules it imposed on companies which were to continue in existence made it inescapable that the device would not again flourish as it did between the end of the first World War and the depression.

From small beginnings, the utility holding company grew amazingly. According to the Federal Trade Commission, subsidiaries of eight large systems generated 72.7% of the output of privately owned systems in 1932.

The authorities agree that there were good reasons why the device flourished as it did. Possibilities from it were real. In a new industry with little investment history behind it and some of that bad, it was difficult to raise the necessary capital. This difficulty was complicated by the local nature of most electricity supply ventures and the national complexion of the money market. Another complication was the high ratio of plant to gross. Any legal corporate device which could offset these financing difficulties was a device to be used, and the utility holding company could work wonders on financing.

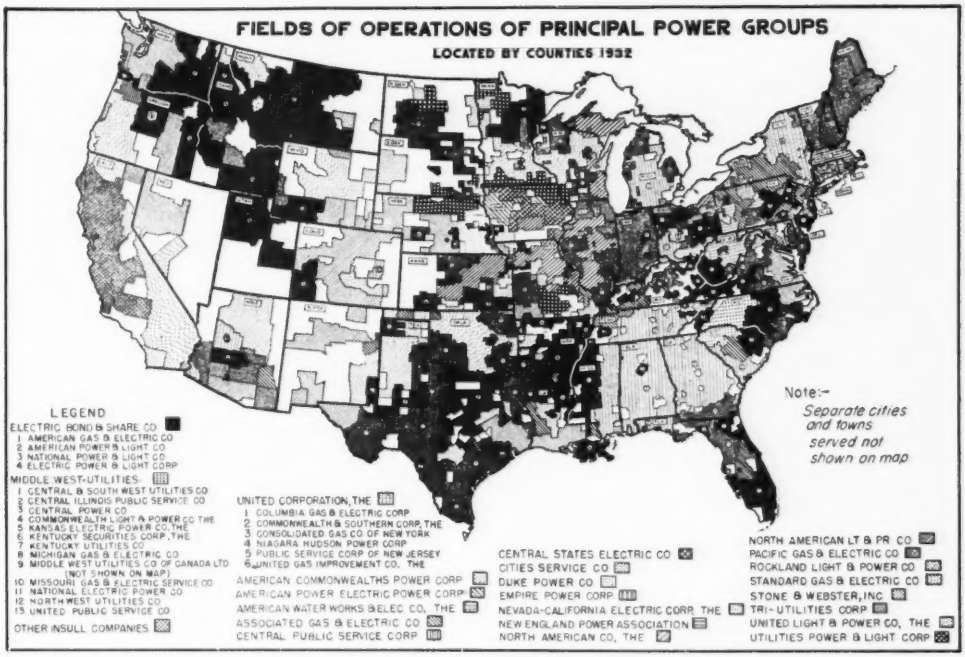
Another particularly significant economic advantage of the holding company lay in its ability to provide small systems with the best available engineering and management—facilities which would not have been available other than on an inter-company basis. The art was a new one and it was developing rapidly. Operation of an electric system involves managerial action, affecting large sums, on matters ranging from scientific problems to the broadest kind of public relations. The service was one which was changing swiftly from a fad to a necessity. The small electric systems of 35 years ago were tailor-made for the type of expert, centralized assistance such as the holding company could render. It was small wonder the holding company flourished.

One of the most ramified of all utility holding companies, the Electric Bond and Share Co, grew out of the early equipment selling success of the General Electric Co. In the industry's first days, manufacturers often had to take the securities of local operating companies in part payment for their wares. After several attempts by GE to sell securities so acquired, EB&S was organized in 1905, to hold operating company securities and supervise the companies themselves. GE's control was discontinued in 1925.

The Stone and Webster group exemplifies another origin of the utility holding company. In the industry's first days, Stone and Webster obtained many engineering and management jobs among independent companies. As the erection of holding company systems flowered, Stone and Webster found it necessary to join the procession if its original business were to be protected.

The North American Co exemplifies the utility holding company which entered the field principally from the viewpoint of an investment group, which saw a need for capital and a chance to supply it profitably.

In retrospect, it seems plain that the chief trouble with the utility holding company device lay in two facts. For one, it was a device which lent itself rather easily to abuse. It dealt with an industry much more vital than many. It offered truly wonderful possibilities to play with other people's money—an attribute which was far from neglected, according to the record. The second fact seems to be that the holding company device suffered from the nature of the era in which it had its greatest application. Certainly one of the major contributing factors to the expansion of the holding company technique during the 1920's was the fact that the state of the electric power art had then progressed to a point at which the next logical trend was consolidation of the small properties which then made up the industry. High voltage transmission was available to link properties effectively. More effective equipment was available to emphasize the wisdom of large—rather than small—power plants.


FIELDS OF OPERATIONS OF PRINCIPAL POWER GROUPS
LOCATED BY COUNTIES 1932
LEGEND
ELECTRIC BOND & SHARE CO
1 AMERICAN GAS & ELECTRIC CO
2 AMERICAN POWER & LIGHT CO
3 NATIONAL POWER & LIGHT CO
4 ELECTRIC POWER & LIGHT CORP
MIDDLE WEST-UTILITIES
1 CENTRAL & SOUTH WEST UTILITIES CO
2 CENTRAL ILLINOIS PUBLIC SERVICE CO
3 CENTRAL POWER CO
4 COMMONWEALTH LIGHT & POWER CO THE
5 KANSAS ELECTRIC POWER CO, THE
6 KENTUCKY SECURITIES CORP, THE
7 KENTUCKY UTILITIES CO
8 MICHIGAN GAS & ELECTRIC CO
9 MIDDLE WEST UTILITIES CO OF CANADA LTD (NOT SHOWN ON MAP)
10 MISSOURI GAS & ELECTRIC SERVICE CO
11 NATIONAL ELECTRIC POWER CO
12 NORTH WEST UTILITIES CO
13 UNITED PUBLIC SERVICE CO
OTHER INSULL COMPANIES
UNITED CORPORATION, THE
1 COLUMBIA GAS & ELECTRIC CORP
2 COMMONWEALTH & SOUTHERN CORP, THE
3 CONSOLIDATED GAS CO OF NEW YORK
4 NIAGARA HUDSON POWER CORP
5 PUBLIC SERVICE CORP OF NEW JERSEY
6 UNITED GAS IMPROVEMENT CO, THE
AMERICAN COMMONWEALTHS POWER CORP
AMERICAN POWER ELECTRIC POWER CORP
AMERICAN WATER WORKS & ELEC CO, THE
ASSOCIATED GAS & ELECTRIC CO
CENTRAL PUBLIC SERVICE CORP
CENTRAL STATES ELECTRIC CO
CITIES SERVICE CO
DUKE POWER CO
EMPIRE POWER CORP
NEVADA-CALIFORNIA ELECTRIC CORP, THE
NEW ENGLAND POWER ASSOCIATION
NORTH AMERICAN CO, THE
NORTH AMERICAN LT & PR CO
PACIFIC GAS & ELECTRIC CO
ROCKLAND LIGHT & POWER CO
STANDARD GAS & ELECTRIC CO
STONE & WEBSTER, INC
TRI-UTILITIES CORP
UNITED LIGHT & POWER CO, THE
UTILITIES POWER & LIGHT CORP
Note:-
Separate cities and towns served not shown on map

Technologically and financially, the industry was ready for thorough application of the integrating, consolidating, expanding virtues of the holding company device.

But the decade in which this was so true was the same decade in which large portions of the adult American population were dedicated to a series of fast rides on borrowed money in a highly speculative stock market. The margin requirement was what you could get from your broker, and call money went to 20%. The standards of the day seem like outrageous fraud today, after 20 years of harrangue, reform and experience. But it was the national pattern of conduct then.

Divestments[1] of Electric Properties by Utility Holding Companies Under Sec. 11 of the Act

Fiscal Year	Electric Companies Involved	Assets of Electric Companies (millions of dollars)
Thru 1944	105	2,957
1945	40	384
1946	29	1,545
1947	19	1,900
1948	26	2,814
Total	219	9,600
No longer subject to Act	165	5,498

Further Divestments Pending, July, 1948

Holding Companies Involved	Subsidiaries (All Types)	Estimated Total Assets
25	183	$5,105,239,520

(1) Does not include partial sales of property made by 67 electric companies. These 67 companies sold electric properties for a total of $97,000,000.

And, because the state of the electric art developed as it did, a device "abusable" in any era was particularly susceptible to misuse during such an era.

Whatever things might have been, in 14 years, the Securities and Exchange Commission has pretty well completed the job of re-aligning the utility holding companies with the public policy laid down in 1935. In 1939, when the Section 11 provisions of the Holding Company Act really began to take effect, there were 55 systems, with assets of $13,917,000,000 which controlled 1,572 subholding companies and other subsidiaries. By June, 1948, only 46 holding company systems were registered, controlling 705 subsidiaries. Value of the shrunken holdings had grown to $14,488,000,000.

By the end of 1951, SEC will have substantially completed its reorganization work under Section 11. There still will be interstate holding companies—perhaps 40 of them. But the survivors will be "integrated" systems. By the Act's definition, that means each system, or holding company group, will control operating electric or gas utilities in a single geographical area, and the systems will largely be shorn of the myriads of second-layer management, or subholding, companies through which they formerly ran their operating properties. Interstate companies will remain subject to SEC regulation of security issues, acquisitions and sales of assets, payments of dividends and other corporate activities covered by the Act. Because of market conditions, some systems may still be shedding properties in compliance with Section 11. But all the major systems should have their divestment programs virtually completed in two more years.

Development of State Regulation

State regulation has maintained a highly constructive attitude in its protection of the customers and the private utilities alike with few recorded cases of irresponsibility

THE FIRST successful attempts to regulate utilities in this country were by municipalities who could pass a city ordinance and control through the franchise provision. The need for direct use of public property made the franchise a satisfactory method of regulation.

The city franchise is still used as an auxiliary means of regulation but it had to be supplemented by state commissions. The abuses growing out of perpetual franchises, and those permitting higher rates or forcing rates lower than were justified, along with the lack of control beyond city limits, brought about many changes in the legislative provisions.

Upon the general dissatisfaction with municipal regulation and the complete lack of regulation in many areas, a movement for state regulation began sweeping the country in 1907. Prior to this time in 1885 the state of Massachusetts formed a commission to regulate gas companies and this was later expanded to include electric light but not power companies. Beginning in 1907, New York created a State Service Commission under the pressure of Charles Evans Hughes. Wisconsin came next through the program of Robert La Follette. Georgia extended the powers of her Railroad Commission to other public utilities. In 1908, Vermont set up a commission, Maryland and New Jersey joined in 1910 and in the next three years seventeen more states followed suit.

Development of Regulating Methods

The basis for determining the value of property upon which the earnings and the corresponding rates could be fixed was defined by the Supreme Court in 1898 by its decision in the famous case of Smyth versus Ames. In this decision, the court held that rates to be valid must yield a fair return on the fair value of the property used and useful in the public service. The two most important elements considered were the original cost of property and reproduction cost.

During the years which this decision predominated in the fixing of rates, the claims as to which factors would receive most weight were based upon the inflationary or deflationary trends of the times. If it were an inflationary period, the company would probably ask for a valuation based upon reproduction cost new and the commission would demand an original cost rate base. In deflationary times, it would likely be reversed. An additional going concern value was allowed in many instances.

Early decisions did not require the deduction of depreciation in the rate base determination, although a credit was usually made for interest on the depreciation reserve.

In the McCardle case decided in 1926, the supreme Court said that the observed depreciation rather than book depreciation could be deducted in determining the rate base.

Utilities objected to any deduction because it precluded the allowance of earnings upon all the property under managerial control of the company. Some of the commissions objected to this method of determining the allowance since they felt that the depreciation reserve which was built up by the rate payers was the amount to be deducted from the gross rate base.

These early methods have not been retained in more recent decisions. In 1942 the Supreme Court held in the Federal Power Commission versus Natural Gas Pipeline Co case that "going concern value" need not be allowed in the rate base. The Hope Natural Gas case decided in 1944 has taken away the Supreme Court sanction of rules set up in Smyth versus Ames and stimulated the use of original cost as differentiated from reproduction cost in determining the rate base. This case also upheld the deduction of a reserve computed by straight line depreciation.

The rate of return allowed for the rate base has varied over the years with changes in the cost of money. In general the allowance has been gradually reduced from a high of around 9% upon a rate base including reproduction cost and going concern value in the 1915 period to as low as around 5% on an original cost rate base with straight line depreciation reserve deducted.

One of the early problems in state regulation was that of setting up appropriate accounting methods whereby an accurate determination of the original cost of property and operating expenses could be clearly identified.

Beginning with the adoption of the Uniform System of Accounts for Electric Utilities by the Federal Power Commission and the National Association of Railroad

State Commission Regulation Practices
(From Federal Power Commission Report FPC S-60)

State	Regulation of Residential, Commercial and Industrial Services			Rate Base Determination		Depreciation Method	Approximate Rate of Return Prescribed %	Uniform System of Accounts Prescribed (1)
	Private	Public	Co-op	Method Applied	Treatment of Depreciation			
Alabama	Yes	No	No	Prudent investment	Deducted	St. line	5½–6½	NARUC
Arizona	Yes	No	No	Prudent investment		St. line generally	6–8	NARUC
Arkansas	Yes	No	No	Prudent investment		Various	6	NARUC
California	Yes	No	Yes	Reasonable hist. cost	Not deducted	Sinking fund	5½–6	FPC
Colorado	Yes	No	....	All elements considered	Deducted	St. line or ret.	5½–6½	NARUC
Connecticut	Yes	No	No	.....	.....	None	5½–6½	NARUC
Delaware	....	....	....	.....	.....	.....	.....	.....
District of Columbia	Yes	....	....	Original cost	Deducted	St. line	5½	FPC
Florida	....	....	....	.....	.....	.....	.....	.....
Georgia	Yes	No	No	All elements considered	.....	.....	5½–6½	NARUC
Idaho	Yes	No	No	Original cost	Deducted	St. line	5½	FPC
Illinois	Yes	No	....	.....	.....	.....	....	NARUC
Indiana	Yes	Yes	Yes	.....	Deducted	.....	....	NARUC
Iowa	....	....	....	.....	.....	.....	....	.....
Kansas	Yes	Yes	Yes	Fair value	Deducted	.....	....	FPC
Kentucky	Yes	No	Yes	.....	.....	.....	....	NARUC
Louisiana	Yes	No	No	Prudent investment	Not deducted	Judg. and hist. record	6	NARUC
Maine	Yes	Yes	No	.....	.....	Retirement	....	Own
Maryland	Yes	Yes	Yes	Fair value '23 plus net add.	Inc. over '23 ded.	.....	5½–6	FPC
Massachusetts	Yes	No	....	Prudent investment	Deducted	St. line generally	....	Own
Michigan	Yes	No	....	Original cost	Deducted	St. line	5–5½	FPC
Minnesota	....	....	....	.....	.....	.....	....	.....
Mississippi	....	....	....	.....	.....	.....	....	.....
Missouri	Yes	No	No	Original cost	Not deducted	St. line	6½	FPC
Montana	Yes	Yes	No	Fair value	Deducted	St. line	6	NARUC
Nebraska	....	No	No	.....	.....	.....	....	.....
Nevada	Yes	Yes	No	Prudent investment	Deducted	St. line generally	6–7	NARUC(2)
New Hampshire	Yes	No	No	All elements considered	Deducted	St. line	5½–6	Own
New Jersey	Yes	No	Yes	All elements considered	Deducted	St. line generally	5½	NARUC
New Mexico	Yes	No	No	Original cost adjusted	Deducted	St. line generally	5½–7	NARUC
New York	Yes	Yes	No	Original cost	Deducted	St. line	5 0	NARUC(2)
North Carolina	Yes	No	No	All elements considered	Deducted	St. line	....	FPC
North Dakota	Yes	No	No	Prudent investment	Deducted	.....	6	NARUC
Ohio	Yes	No	....	Reproduction cost	Deducted	Observed	....	Own
Oklahoma	Yes	No	No	Original cost	Deducted	.....	5½	FPC
Oregon	Yes	No	No	Original cost	Deducted	St. line generally	6	NARUC
Pennsylvania	Yes	No	No	Fair value	.....	.....	6	FPC
Rhode Island	Yes	Yes	....	.....	.....	.....	....	Own
South Carolina	Yes	No	No	Fair value	.....	.....	....	NARUC
South Dakota	....	....	....	.....	.....	.....	....	.....
Tennessee	Yes	No	No	Prudent investment	Deducted	St. line	....	FPC
Texas	....	....	....	.....	.....	.....	....	.....
Utah	Yes	No	No	Prudent investment	Deducted	.....	6	NARUC
Vermont	Yes	Yes	No	.....	.....	.....	....	NARUC(2)
Virginia	Yes	No	Yes	Fair value	Deducted	Comp. interest	5–6½	NARUC
Washington	Yes	No	No	Original cost	Deducted	St. line generally	....	NARUC
West Virginia	Yes	Yes	Yes	All elements considered	Deducted	Insp. and co. exper.	5½–6½	NARUC
Wisconsin	Yes	Yes	No	Fair value	Deducted	St. line generally	6	NARUC
Wyoming	Yes	Yes	Yes	.....	.....	.....	....	None

(1) FPC and NARUC systems of accounts only vary to a minor degree. (2) FPC or NARUC.

THE MORE IMPORTANT FACTORS in state regulation follow a similar pattern in most states except rate base determination and control of rural co-operatives and public power agencies

and Utility Commissioners in 1936, substantial progress has been made. That accounting system is in effect today for over 95% of the electric utility industry, as measured by assets or revenue. Growing out of the adoption of the uniform system of accounts which requires separation of original cost of property, practically all systems have made adjustments in plant accounts to this basis. As of the latter part of 1948, the Federal Power Commission had issued orders for account adjustments in the amount of almost one and one-half billion dollars. This representing more than 10% of the original cost of property.

Regulation has included other items than rate of return, depreciation and accounting methods. The state commissions have jurisdiction over the rate schedules, rules and regulations for providing service, service standards, issuance of securities, and other elements involving the use of equipment.

Present Status of Regulation by States

Up-to-date statistics regarding state regulations are presented in the recent publication of the Federal Power Commission entitled "State Commission Jurisdiction and Regulation of Electric and Gas Utilities". This booklet states that all but 8 of the 48 states including the District of Columbia have Commissions with power to regulate the rates of privately owned electric utilities. The states of Delaware, Florida, Iowa, Minnesota, Mississippi, Nebraska, South Dakota and Texas have no commission regulation of electric utilities. In Delaware, the State Legislature exercises control over franchises and in Texas the cities exercise jurisdiction. In Nebraska, almost all facilities are publicly or co-operatively owned, with the railway commission having certain powers over franchise areas, accounts and records, and sale of facilities.

Most commissions are without power to regulate the rates of publicly owned and cooperatively owned electric utilities. Eleven have regulatory powers regarding publicly owned utilities and nine for cooperatives.

The high caliber of most commissions, their belief in state control of regulation, and the survival of the private systems should be a strong force in maintaining a high standard of regulatory practice.

Developments in Rate Making

Electric rates have changed in form to satisfy industry requirements but desired simplicity accurately reflecting cost of service is still being sought

THE DREAM of the rate maker has always been a schedule that would collect the full cost of rendering the service for any kwhr used by any type of customer served. But the rate maker, who is usually technically inclined, has been faced with the problem of conforming to the demands of the politician, the salesman, the sometimes arbitrary needs of the moment and the impossibility of complete accuracy.

All these factors plus the changing outlook and use of electricity have caused distortions in the rate forms in all periods in the history of rate making.

Today the trend is toward the more exact determination of cost of service for each kwhr supplied but many hurdles will have to be surmounted before such a condition can be realized. In fact, the differences in individual customers would prevent the setting of a rate schedule which would be even approximately correct for more than one customer.

Early Rates

Upon the origin of electric service, the capital cost was very large compared with the consumption by the customer. At that time a "flat rate" for service came close to satisfying the needs of the supplying company. This form of rate has always been the ultimate in simplicity and has therefore been the unattainable goal of the practical business executive.

Since the cost of energy ran high at fuel rates of eight pounds per kwhr, the use of energy soon became an important factor in the rate making.

To get at this problem it was found that a rate based upon the number of outlets in active use gave a measure of consumption. It was called the "fixture rate." This was one of the early rate forms and a modification is still used as a "room rate" in a number of localities for residential service. It became popular in the 1920-30 period and is based upon the number of active rooms.

Following the use of these rates based upon nonmetered service came those based upon the measured energy consumption of the customer.

Here then the rate maker had a tool for distributing the cost of service in some relation to the three important elements of customer's use involving customer, demand and energy cost.

The minimum bill which was an outgrowth of the "flat rate" was used to cover some of the customer costs. The desire to spread the cost of service more in terms of ability to pay has prevented the minimum bill from entirely carrying the whole customer cost when applied to residential customers. This device is used in practically all rate schedules.

The uniform rate for each kwhr which was first used had many serious defects. It made no distinction between demands of the customer or the time of use of such demands. It gave no credit to the large user over the small user. There was no incentive for the customer to expand his use; in fact, at the then prevailing energy rates, there was a marked deterrent.

A recognition of these short comings caused the use of a discount feature for additional kwhr. This led the way for the development of the step rate which provided for a reduced charge per kwhr for various amounts of use such as:

50 kwhr or less per month.....9¢ per kwhr
50-100 kwhr per month.....8¢ per kwhr
100-200 kwhr per month .....7¢ per kwhr

This form of rate was termed regressive by the commissions, since it tended to give free kwhr at the breaking point in the steps, and there was no provision for differentiating between types of customers. By 1929 this form of rate had practically disappeared.

Development of Present Rate Forms

The next development in rate making was the block rate. This rate overcame certain objections of the step rate and is now in use for the majority of residential and small commercial customers. It takes this form:

First 50 kwhr or less.....4.0¢ per kwhr
Next 50 kwhr.....3.0¢ per kwhr
All use over 100 kwhr.....1.5¢ per kwhr

The lack of a measure of the customer's demand is one of the principal defects of this type of rate. Since a residential customer uses his maximum demand for only a few hours per month, the group demand of all residential customers is the most important factor. So the application of the block rate can be made to supply the total revenue requirements of the group but will not provide an accurate charge for any single customer.

This same principle applies to the small commercial customer. But the customers within this group tend to have maximum demands at the same time so the blocks must include a higher unit charge to cover a greater demand cost.

For the larger customers, where the additional expense could be carried, the use of demand measurement came into use. The Hopkinson two-part-rate was developed for this purpose. Here the customer paid a set rate per kw of maximum demand plus a charge for energy consumption under the block rate. It took the form of:

Demand Charge—
First 10 kw of maximum demand.....$1.50 per kw
Excess over 10 kw.....$1.15 per kw

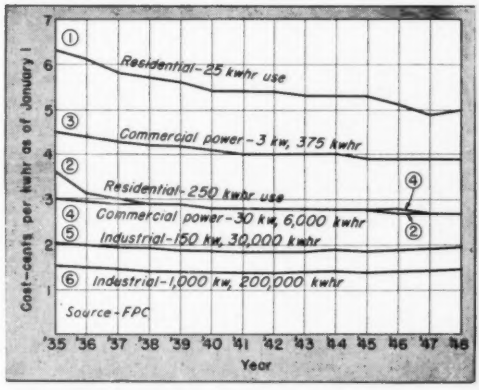
Energy Charge—
Same as block rate

By the use of this rate form any size of customer could be charged equitably compared with other customers within reasonable limits.

The demand charge does not ordinarily cover all the costs which are proportionate to this element. Part of this is usually included in the energy rates. If all related charges are in the demand charge, the rate gives accurate correction for customer load factor, because increased use of energy without increase in demand only invokes incremental energy cost. The objection is that the higher load factor customers have less diversity in demand. That is, two 100% load factor customers must have their peaks simultaneously. The only practical way of assuring an adequate provision for reduced diversity growing out of high load factor is the inclusion of some demand costs in the composition of the energy rates.

Special Features

An early development which failed to provide for the relationship of diversity in rate making was the Wright rate. This was a mixed demand and energy charge based upon the number of kwhr used per kw of demand. It was developed to take into consideration the load factor and size of customer. The consumption is divided by the maximum demand to get the kwhr per kw. For instance, a customer with a high load factor might use 400 kwhr per kw of demand, the poor customer 200 kwhr per kw. So the charges would be set higher for the first 200 kwhr than the second 200 kwhr to allow credit for the improved load factor. This form of rate can be used in connection with actual demand readings or estimated demands. It was used to a considerable extent some years ago but is now of less importance principally due to its complexity.


Cost-cents per kwhr as of January 1
Residential-25 kwhr use
Commercial power-3 kw, 375 kwhr
Residential-250 kwhr use
Commercial power-30 kw, 6,000 kwhr
Industrial-150 kw, 30,000 kwhr
Industrial-1,000 kw, 200,000 kwhr
Source-FPC
'35 '36 '37 '38 '39 '40 '41 '42 '43 '44 '45 '46 '47 '48
Year

THE AVERAGE COST of energy to the customer depends upon his use and load characteristics. The 25 kwhr customers pay little more than billing cost whereas the industrial customers pay little more than average production cost.

In order to equalize the demand charges between customers and spread the cost over a yearly basis many companies use a ratchet which provides that demand charges in any one month must be some percentage of the charge in the month of maximum demand. This provision ties each month's charge into the annual maximum demand which is the controlling factor in cost of service.

Variation in demand charges for different seasons has been used extensively. The Winter evening peak has long been the highest for most companies. Since the system capacity was installed to carry this peak, it was logical that customer demands coming during this period were creating more expense than those at a different time of day or season. Higher charges were made by some companies for these periods. Recently the changes in load characteristics to flat all-day peaks, effects of summer air conditioning, and the use of interconnections to spread diversity have lessened the need for such provisions.

Since system investment is related closely to the number of voltage transformations, rates have been built around certain voltage ranges. For industrial use voltages of around 13,800, 11,000, 4,000 and 2,300 have been used extensively. A frequently used device is a rate based on 4-kv three-phase or 2.3-kv single-phase primary. When the customer supplies his own transformers he is given around a 5% discount. When high voltage service is supplied, the customer usually supplies his own voltage regulation. This is not the case for 4-kv or low voltage service.

The use of three phase for motors for residential and farm use is becoming a serious problem because of the higher cost of this type of service. The farm customer creates the greatest problem because so many miles of line are involved in providing three-phase power to outlying areas.

As explained above, the form of the two-part-rate generally corrects for the load factor. Since this rate is applied only to large customers, the small customer will pay on the basis of the average for his group.

Many rates for industrial service provide penalties for power factors below 80% and credit is often allowed for higher power factors.

Fuel Clauses

Fuel clauses were commonly used in commercial power and industrial rate schedules in the past 25 years but many were inoperative due to the price of fuel. Only half the major companies had fuel clauses in industrial rates in 1941 and over half of these were inoperative. However, by 1948 over two-thirds had such provisions and almost all were operative. The substantial increase in fuel cost created an immediate need for the use of fuel clauses to maintain revenues. Many utilities extended this feature to residential and small commercial rates but often made them applicable to kwhr in excess of some fixed amount of use. Fuel cost increased from 9% of revenue for the average company in 1941 to 18% in 1948.

Discounts for prompt payment of bills or additional charges for failure to pay promptly have been used extensively. These schemes have worked effectively but the recent trend has been toward lower discounts or complete abandonment. Many reductions in discount came as a means of increasing revenue during 1948.

Most companies have provided for special rates for water heating. Until recent changes related to the increased fuel cost, most utilities charged 1¢ per kwhr for controlled offpeak service. Others provided a low rate block for consumption beyond the other normal uses which usually included lights, small appliances, range and refrigerator.

Recently provisions have been made for increases in the rate blocks for use of house heating which has a different characteristic from other types of load. A special demand charge has also been applied by two utilities to collect the full cost of this service.

The charges for service to large industrial companies, street railways and municipal functions are usually special contracts differing from the rate schedules. These special contracts provide for the unusual conditions which have to be met in connection with these customers including load factor, power factor, service capacity, special voltages, short time demands, customer generating facilities, joint use of facilities, emergency service connections and many other features.

Street lighting rates often include the furnishing and maintaining of fixtures along with turning on and off night and morning. They are often far too complex in form and therefore need simplification.

Cost of Service

As a guide for determining the cost of service which must be recovered from each class of customer, many utilities use cost allocations. These allocations segregate the total cost of doing business between the expense related to customer, maximum demand and energy.

Costs which are a function of the number of customers are allocated in that way. They include sales expense, billing, bookkeeping, meter reading, customer services, and carrying charges for certain minimum system investment including such things as services and meters.

Energy cost includes principally fuel, production plant maintenance and some operating labor. It is allocated in accordance with kwhr use.

Demand cost includes the carrying charges on most system investment, operating labor and maintenance other than power plant. There are a variety of methods of allocating demand costs. Perhaps the most commonly used measure is the relation of maximum class demand of each group of customers to the sum of the individual class demands. The proportion of each to the maximum system demand has also been used. To be very precise, it is probable that production plant and transmission costs should be proportioned to annual system peak responsibility and remainder of system costs allocated on the basis of class demand.

The actual setting of rates based upon cost allocations involves many other considerations. If one assumes that each class of customer should carry its total cost rather than using the value of service to the customer as a basis of charge, he must still decide where among the three elements—minimum charge, energy charge, and demand charge—the cost shall be allocated.

Due to the small margins with which the rate maker has to work, it is becoming essential for him to make careful cost allocations to assure an adequate return.

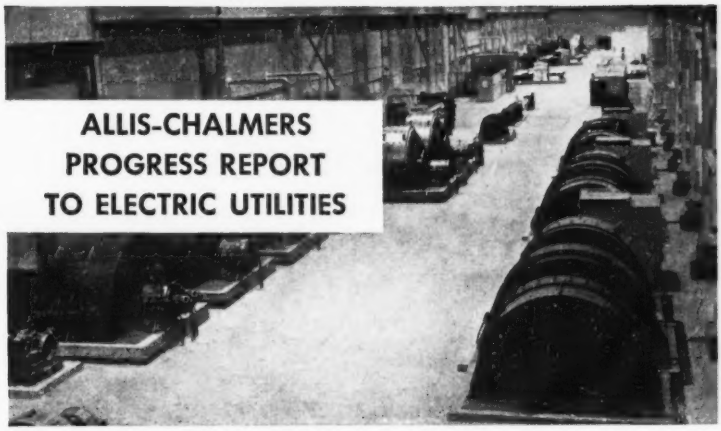
The commissions are finding cost allocations a very useful tool in gauging the reasonableness of rates proposed by the utilities but they have sensibly shied away from using them as the only criterion.

Further simplicity in electric rates has always been the goal of sound utility management. In the past few years consolidation of rate schedules has gone at a rapid rate toward the ultimate goal of three or four schedules for one locality covering residential, farm use, small light and power and large light and power. The lack of information on the farm load, television, house heating and cooling has prevented the accurate solution of the billing problems for these services. Many companies have tended to overcharge in order to assure coverage of these usages. Ultimately when their use becomes more widespread and diversity increases, lower rates will probably be set.

Control of Loads

The control of loads through use of time clocks, carrier current, and load limiters can be useful for residential service. An expansion in the use of these devices is to be expected since they offer the only practicable method of supplying service for these heavy uses at a low rate.

The need for rate increases which have been granted during the 1948-49 period have been based principally upon the increased cost of fuel and operating labor. As the expansion program advances, the depreciation expense and other carrying charges will increase materially and the charges for these factors will probably have to go up. Fortunately, the increased use of energy which is predicted over the same period should be a major force in keeping the average cost of electrical energy close to the present level.



ALLIS-CHALMERS PROGRESS REPORT TO ELECTRIC UTILITIES

43,800 HP ROLLING STEEL! Typical of A-C Power, Electrical, Processing equipment

Load-Building, Cost-Cutting A-C Products

H. A. Bartling
Mgr., Electronics

DURING THE PAST YEAR A-C advanced production not only in electric power equipment, but in actual electric load-building equipment as well.

MOTORS. New, protected general purpose motors in drip-proof and totally-enclosed types are now offered to industry in sizes from ½ through 20 hp. New tube-type TEFC and explosion-proof motors from 75 through several thousand hp have been marketed for powerhouse, chemical and petroleum needs. Improved maintenance, protection are stressed.

STARTERS. The line has been expanded to meet practically all requirements from the smallest manually-operated across-the-line starters to the largest high capacity units. You can now get an Allis-Chalmers starter for *any* size motor!

ELECTRONIC EQUIPMENT. Allis-Chalmers Induction and Dielectric Heaters, and Metal Detectors, widest line in industry, are helping users cut unit costs, improve products, protect quality.

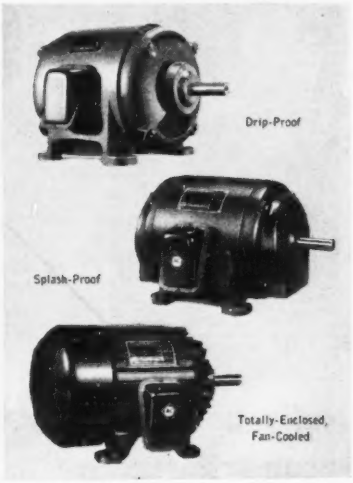
BETATRONS. A-C has opened the world's first commercial betatron laboratory, providing open time for high-speed radiography and research. Five 24,000,000 volt betatrons have been shipped for medical, and nuclear research.

NEW CAR SHAKER. Introduced for power plants and industries requiring fast unloading of frozen coal or other materials from hopper-bottom cars.

On the equipment side, utilizing electric power, emphasis has been on mechanization—more A-C crushers, hoists, screens, huge steel mill motors, shakeouts. In cement, A-C rotary kilns, long as 475', are electric-powered. A new petroleum pipe line will use 29 A-C tube-type motors. In public works, huge A-C pumps from 5 to 21 mgd, are being installed. In pulp and paper a total of 16,000 hp of motors, a 170' kiln and 46 pumps are going into one plant! These examples are typical.

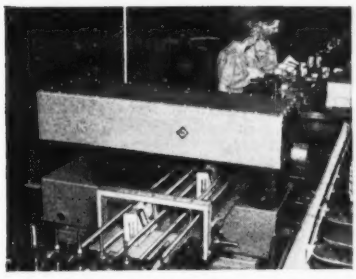
Building equipment for . . . and promoting applications of . . . *electric power* is the No. 1 job of the General Machinery Division of Allis-Chalmers! Over 65 years in electrical equipment, 102 years in industrial, are concrete evidence of Allis-Chalmers' stake in the Electric Power Industry! ALLIS-CHALMERS, 932A S. 70TH ST., MILWAUKEE 1, WIS. A2722

HIGH PRODUCTION 20-kw induction heater

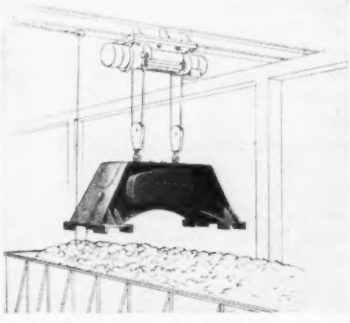


"SAFETY-CIRCLE" MOTORS—more protection

15-KW DIELECTRIC heater for wood-gluing



METAL-DETECTOR safeguards consumer products



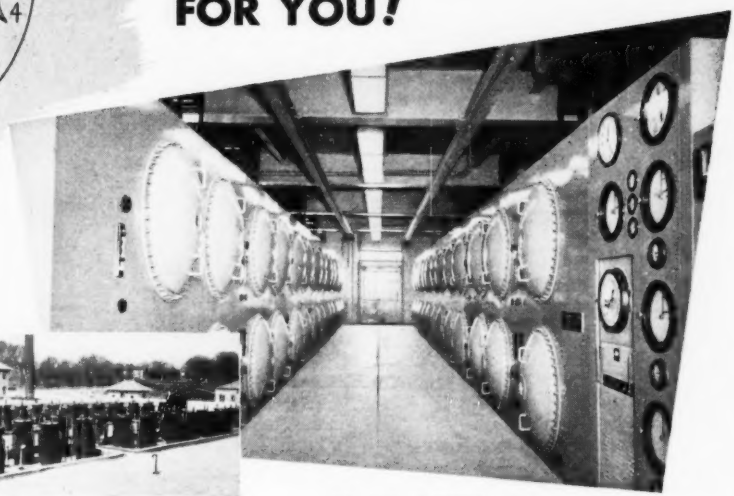
ELECTRIC-POWERED car shaker loosens coal, etc.

Safety-Circle is an Allis-Chalmers Trademark

ALLIS-CHALMERS A-C

Pioneers in Power and Electrical Equipment—Builders of the World's Widest Range of Major Industrial Equipment!

Builds "around-the-clock" Load FOR YOU!



Roof-top transformer banks at the Belmont plant, for handling power load to the banks of Welsbach Ozonators shown above.

Twin banks of Welsbach Ozonators at Philadelphia's Belmont Filtration Plant, for electrical generation of ozone in water treatment.

Electrically-generated *Ozone* for water treatment

Do you want new load on existing lines? You'll want to know more about The Welsbach Corporation's newly-developed ozonation process, which builds electric load while generating ozone gas for water purification. An outstanding unit of electrically-operated ozone generators, installed at Philadelphia, is shown above.

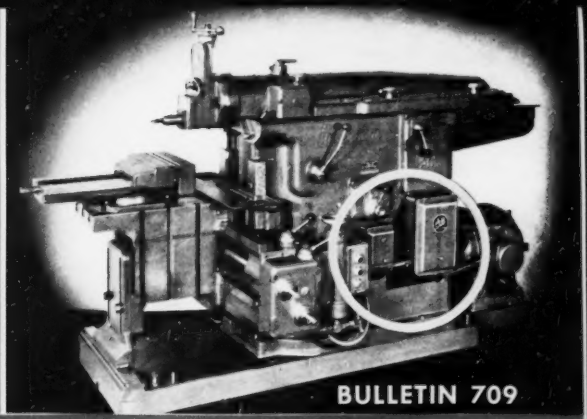
This "around-the-clock" load factor can mean a lot for *your* system, too. At the Philadelphia ozonation installation, power utilization averages about 200 kwh per million gallons of water handled – and one Philadelphia ozonation installation alone has an eventual capacity of 70,000,000 gallons of water daily! In addition, the ozonators produce a leading power factor which normally balances some or most of the lagging power factor produced by other electrical equipment at the water plant.

If you operate water plants . . . or if municipalities you serve face surface water treatment problems of bad taste, odor or color due to pollution, investigate the possibilities of Welsbach ozonation. Have your commercial department write today for latest information on this new load-building opportunity for existing lines.

THE WELSBACH CORPORATION
OZONE PROCESSES DIVISION
1500 Walnut Street **Philadelphia 2, Pa.**

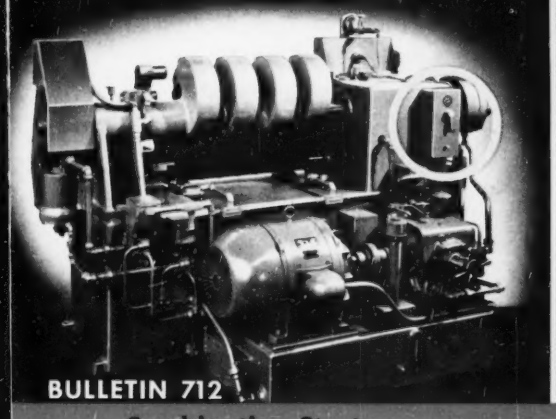
BULLETIN 609

Manual Starters



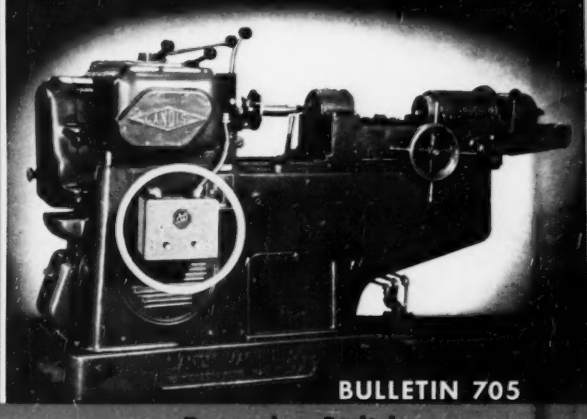
BULLETIN 709

Automatic Starters



BULLETIN 712

Combination Starters



BULLETIN 705

Reversing Switches

TROUBLE-FREE Motor Controls for Every Machine Tool Requirement

This A-B name plate on motor controls is an internationally famous trademark . . . recognized by machinery buyers as the emblem of top quality in motor control. It stands for a solenoid contactor construction having only one moving part. It stands for double-break, silver-alloy contacts that never need maintenance. It stands for freedom from pivots, pins, and bearings. It stands for millions of trouble-free operations.

Bulletin 800T oiltight station.

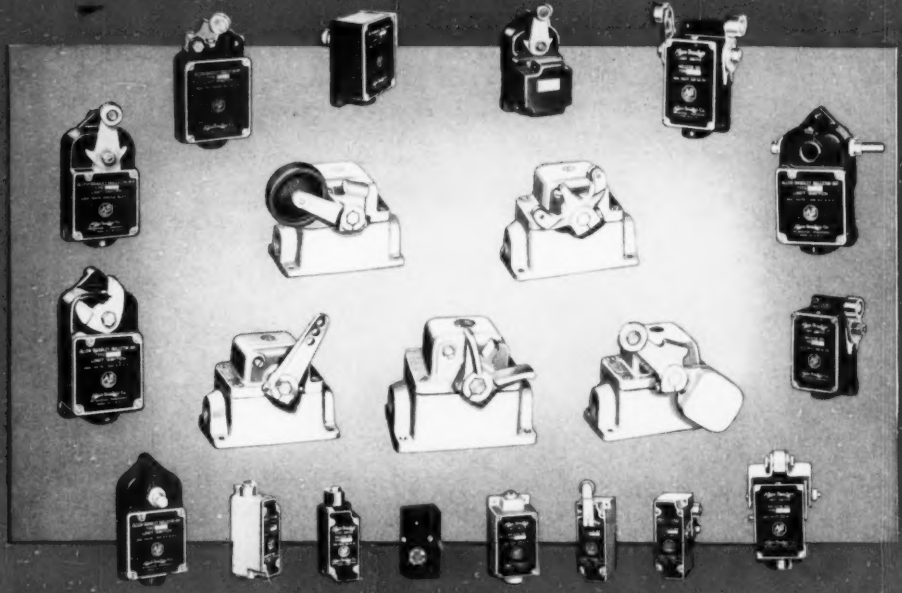
You can add a valuable sales asset by equipping your machines with A-B motor controls. The A-B name plate assures you and your customers of freedom from control troubles.

Allen-Bradley Co., 1316 S. Second St., Milwaukee 4, Wis.

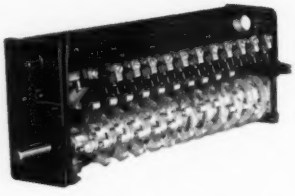
ALLEN-BRADLEY

QUALITY

SOLENOID MOTOR CONTROL



Do you have Sequence Control Problems?



Rotating Cam Limit Switch

The new Bulletin 801 limit switch will handle from 3 to 12 circuits. Each cam independently set for position and angular travel. Double-break, silver-alloy contacts assure dependable operation.

Let Allen-Bradley Control Engineers help you select the most suitable limit switch for each application

Limit switches . . . hundreds of types and sizes in the Allen-Bradley line . . . are the "makings" of modern sequence control systems.

Some of the more popular A-B limit switches are shown above. With this big line to pick from, you can put any machine through its paces . . . step up its performance . . . and obtain the automatic sequence control you require.

If you really want to see "what's cooking" in limit switches, ask an A-B control engineer to drop in. There's no obligation . . . it's a friendly service to machinery builders who want up-to-date motor controls on their machines.

Allen-Bradley Co., 1316 S. Second St., Milwaukee 4, Wis.

A-B Quality

ALLEN-BRADLEY

SOLENOID MOTOR CONTROL

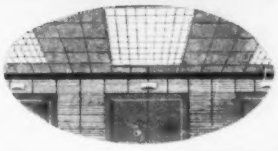
QUALITY

NEW! Day-Brite's FOUR-BY-FOUR unit

Incorporating the most advanced principles of integrated lighting, offering new architectural possibilities

FOR OFFICES

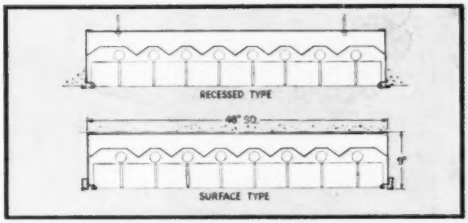
SMALL RETAIL STORES



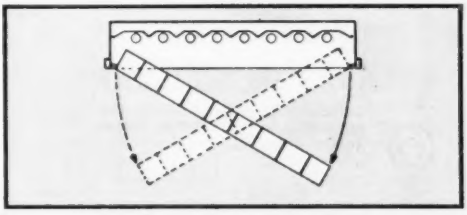
ENTRANCES, LOBBIES

LARGE DEPARTMENT STORES

Day-Brite's Four-by-Fours are engineered for both recessed and surface mounted applications. They can be used with 6, 8, and 10 40-watt fluorescent lamps. Knockouts are provided for feed connections. Plaster frames are available for use when fixtures are recessed.



Separable hinges on both sides of louvers allow hinging from either side for easy servicing. Exclusive Day-Brite BOXCO louver assembly has double-wall louvers interlocked for extreme strength and rigidity. Fixtures are rust-inhibited and finished in Hot-Bonded Super-White enamel throughout.



IT'S EASY TO SEE WHEN IT'S

DAY-BRITE *Lighting*

239

Write NOW for descriptive Bulletin 20-C

Day-Brite Lighting, Inc., 5425 Bulwer Avenue, St. Louis 7, Missouri

In Canada: Amalgamated Electric Corp., Ltd., Toronto 6, Ontario

Day-Brite fixtures are engineered for every seeing task. Distributed nationally through leading electrical wholesalers

ON and ON and UP and UP!

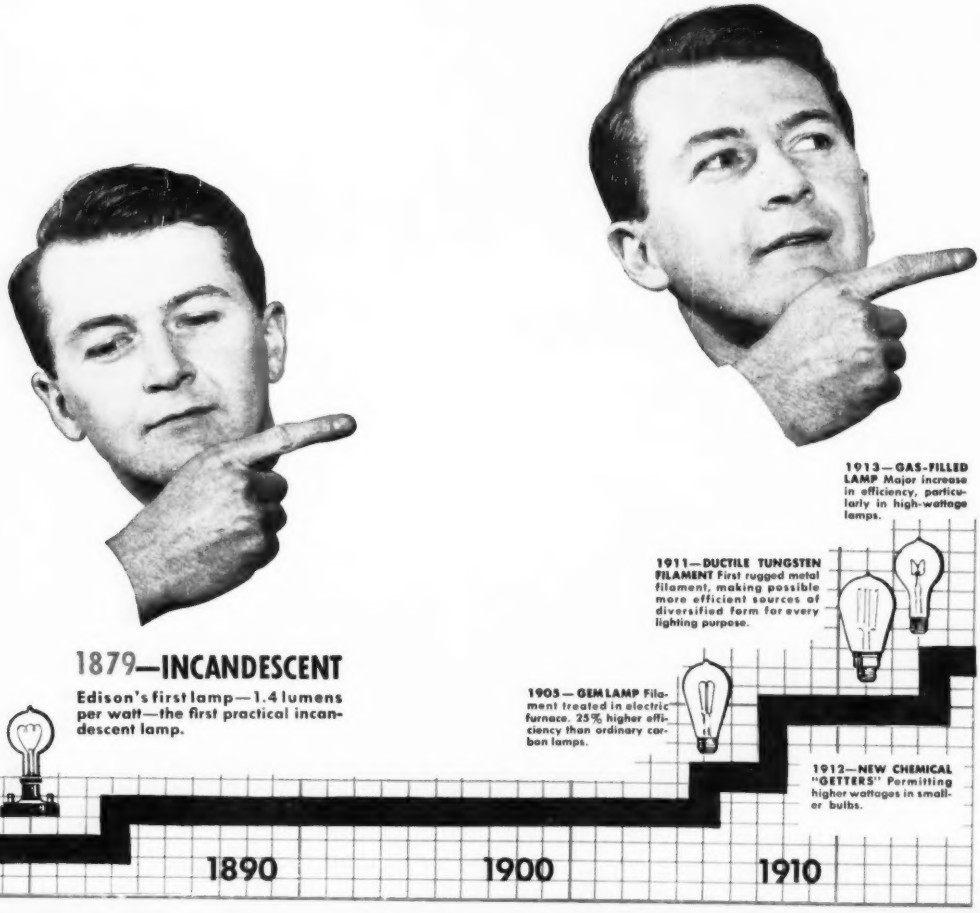
EVER since the development of Thomas Edison's first practical incandescent lamp 70 years ago, General Electric Lamp research has been constantly at work to make lamp bulbs better.

This graph tells the story.

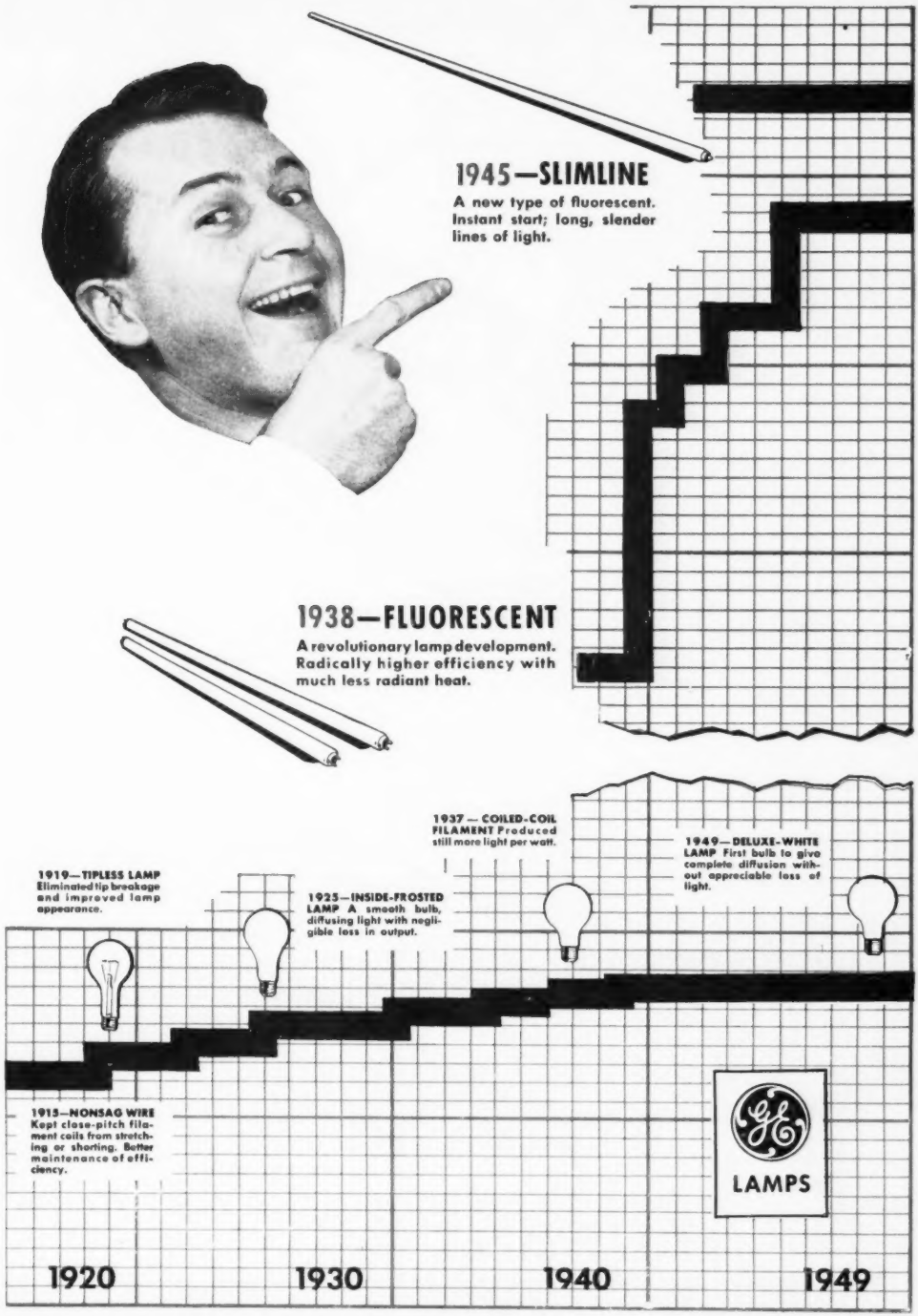
As General Electric Lamp research has continued steadily onward, the efficiency of G-E lamps has gone steadily upward, until today slimline fluorescent gives 50 times as much the light per watt as Edison's lamp of 1879.

Through giving customers greater and greater lighting value, General Electric has helped increase the use of better lighting everywhere. And an important assurance of ever-growing lighting business for utilities is the General Electric Lamp research which is always at work to make G-E lamps *STAY BRIGHTER LONGER!*

GENERAL ELECTRIC


1879—INCANDESCENT
Edison's first lamp—1.4 lumens per watt—the first practical incandescent lamp.
1890
1900
1910
1903—GEM LAMP Filament treated in electric furnace. 25% higher efficiency than ordinary carbon lamps.
1911—DUCTILE TUNGSTEN FILAMENT First rugged metal filament, making possible more efficient sources of diversified form for every lighting purpose.
1912—NEW CHEMICAL "GETTERS" Permitting higher wattages in smaller bulbs.
1913—GAS-FILLED LAMP Major increase in efficiency, particularly in high-wattage lamps.

Lighting's share of total electrical energy used


1945—SLIMLINE
A new type of fluorescent. Instant start; long, slender lines of light.
1938—FLUORESCENT
A revolutionary lamp development. Radically higher efficiency with much less radiant heat.
1937—COILED-COIL FILAMENT Produced still more light per watt.
1949—DELUXE-WHITE LAMP First bulb to give complete diffusion without appreciable loss of light.
1919—TIPLESS LAMP Eliminated tip breakage and improved lamp appearance.
1925—INSIDE-FROSTED LAMP A smooth bulb, diffusing light with negligible loss in output.
1915—NONSAG WIRE Kept close-pitch filament coils from stretching or shorting. Better maintenance of efficiency.
LAMPS
1920
1930
1940
1949
LUMENS PER WATT

increased from 24% to 30% between 1936 and 1946

In considering your needs for WIRE... CABLE... CONDUIT

FOR *Extra* QUALITY — AT NO EXTRA COST — INSIST ON TRIANGLE

Benefit by Triangle's 3 PRINCIPAL POINTS

1 THE PRODUCT
(If It's made by Triangle, IT MUST BE RIGHT!)

2 THE PERFORMANCE
(Triangle products have delivered proved performance since 1916!)

3 THE PRICE
(Triangle's pricing policy, combined with top quality, means utmost value!)

FOR EXAMPLE:

. . . IN BUILDING WIRE . . .
Triangle's outstanding development of its "Glazon" protective covering has set new standards for longer life, stronger construction, and resistance to fire, heat and moisture. "Glazon's" smaller diameter affords greater flexibility, improved fishability!

. . . IN TRENCH CABLE . . .
Triangle's new "Trioprene" trench cable answers a long felt need for a light, flexible, easy-to-handle cable for direct earth burial. Its special Neoprene jacket resists attack by various soil conditions . . . also withstands sunlight, making "Trioprene" ideal for aerial installation, too!

. . . IN STEEL CONDUITS . . .
Triangle's Hot Dipped Galvanized Conduit and Hot Dipped Galvanized Thinwall Conduit have earned an enviable reputation in the electrical industry by maintaining, both on the outside and inside, the most uniform galvanized coating. Where corrosive conditions are really tough — in chemical plants, around refineries, on bridges over salt water — customers specify Triangle conduit and E.M.T. again and again!

NEW!
Triangle's *compact* . . . *easy to use* . . . *condensed* catalog. Write for your copy today!

If It Bears this Trade Mark It's Made by Triangle
If It's Made by Triangle — IT MUST BE RIGHT!

ARTERIES FOR ELECTRICAL SYSTEMS INCORPORATED

IT MUST BE RIGHT!

TRIANGLE CONDUIT & CABLE CO., INC.
1900 JERSEY AVENUE • NEW BRUNSWICK, N. J.
PLANTS: NEW BRUNSWICK, N. J. • MOUNDSVILLE, WEST VA.

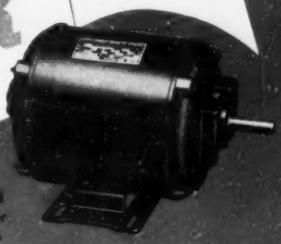
"GLAZON" BUILDING WIRE • BARE WIRE • ARMORED CABLE • "GLAZON" TRIEX NON-METALLIC SHEATHED CABLE • SERVICE ENTRANCE, SERVICE DROP, VARNISHED CAMBRIC BRAIDED OR LEADED, TRIOPRENE TRENCH, POWER AND PARKWAY CABLES • RIGID CONDUIT HOT-DIPPED GALVANIZED • ELECTRIC METALLIC THIN WALL CONDUIT • FLEXIBLE STEEL CONDUIT

1891

WAGNER

1949

1896 DESIGN
Single-phase Motor
½ HP—1800 RPM
Weight 150 pounds



1949 DESIGN
Single-phase Motor
½ HP—1800 RPM
Weight 32 pounds

58 YEARS OF SERVICE TO THE ELECTRICAL INDUSTRY •

FAMOUS WAGNER FIRSTS

First commercially-successful self-starting single-phase motor.

First brush-lifting motor.

First starterless polyphase motor.

First general purpose power-factor correcting motor, known as the Fynn-Weichsel motor.

First dust-tight, totally-enclosed fan-cooled motor.

Wagner Electric Corporation is proud to be the maker of products that have contributed materially to the growth and progress of the electrical industry. But Wagner is not content to rest on its laurels—the pioneering spirit that developed these Wagner *firsts* in electric motors is still the motivating force at Wagner and is reflected in the continuing Wagner reputation for quality and dependability.

Wagner Electric Corporation
6456 PLYMOUTH AVE., ST. LOUIS 14, MO., U. S. A.

Electrical Equipment And Automotive Brake Products

M49-21

An Oscar TO YOU WHO SELL

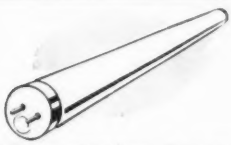
Planned Lighting...

How many of these 8 recent Westinghouse Load Builders are you promoting?

Planned Lighting is now well accepted by all phases of industry. But you who promote Planned Lighting, and we who manufacture the products for it, have a continuing opportunity to extend its scope as new and improved lamps are produced. Here, for example, are some recently developed Westinghouse lamps that can contribute substantially to load building.

★ **85-watt Fluorescent** — New high-efficiency lamp handles any large scale lighting job with ease—such as offices, factories and stores.

★ **25-watt Fluorescent**—Simple, inexpensive fixture requirements, make this fluorescent ideal for both commercial and residential lighting.



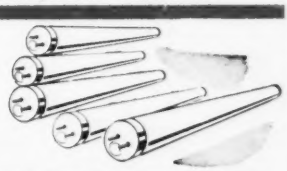
★ **Fluorescent Sun Lamp**—The most powerful sun lamp ever made. Ideal for offices, plants, stores, schools, hospitals, gyms, etc.

★ **Slimline—Instant Start**—96" long T-12 fluorescent tubes are specially designed for continuous row lighting, window displays, decorative and architectural lighting.

★ **New 75-watt R-30 Spot and Flood**—Small and powerful with built-in reflector. Good for store display lighting and for supplemental lighting everywhere—especially where space for the bulb is limited.

★ **New 150-watt Indirect Lite Bulb**—This new light bulb is being used to modernize old portable lamps and is also being used by many fixture manufacturers for newly designed lamps.

★ **Circlarcs**—Used singly or in multiple units, these ingenious fluorescents are perfect for display or decorative lighting or for unusual designs in architectural lighting.



★ **New Fluorescent Colors**—Warm white, with its "incandescent" color, has joined the ranks of these other popular favorites: Daylight, White, 4500 White, and Soft White.

YOU CAN BE SURE...IF IT'S

Westinghouse

THE NAME YOU KNOW IN Light Bulbs

G-45-30-2-P

What does this FLEUR-O-LIER INDEX SYSTEM NUMBER MEAN?

In a specification, it denotes the exact kind of lighting performance desired. "G" stands for General Diffuse lighting distribution; "45" for 45° side shielding; "30" for 30° end shielding; "2" for a brightness in shielded zone of not more than 2½ footcandles per square inch; "P" means Pendent mounting.

For a fixture, those symbols mean that Electrical Testing Laboratories, Inc., after photometric tests, find it has those performance characteristics.

Thus, it is now possible for the specifier to express simply and precisely the lighting performance he wants. And the buyer can now buy fixtures and know in advance how they will perform when installed. For, in addition to the Index System rating, complete photometric data, together with coefficients of utilization are supplied for each Fleur-O-Lier fixture,

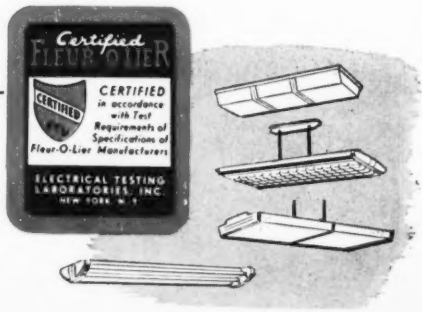
And the Fleur-O-lier label certifies that the fixture is "right" mechanically and electrically.

Fleur-O-Lier Gives *Complete* Information —

All the data needed to make an intelligent choice of fixtures is provided by Fleur-O-Lier. You get—

1. An Index System Rating
2. Photometric test data
3. Coefficients of Utilization
4. Certification

You're *sure* when you insist on Fleur-O-Lier.



FLEUR·O·LIER

Manufacturers

2116 Keith Building • Cleveland 15, Ohio

Fleur-O-Lier is not the name of an individual manufacturer, but of a group of fixtures made by leading manufacturers. Participation in the Fleur-O-Lier program is open to any manufacturer who complies with Fleur-O-Lier requirements.

WE'RE HONORED TO JOIN YOU, ELECTRICAL WORLD, ON YOUR 75TH ANNIVERSARY

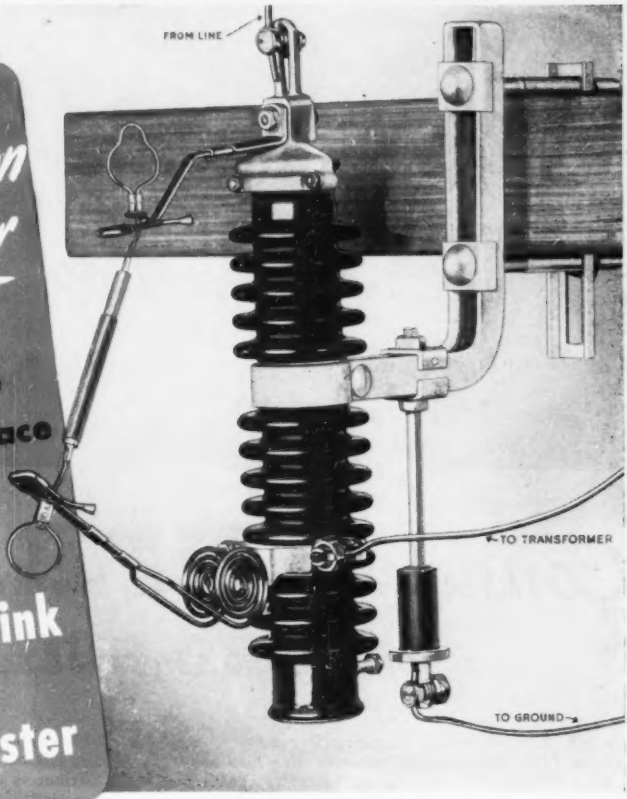
Here's a

Great Combination on One Insulator

to Save You Time and Money and Space

KEARNEY'S

Q.R.C. Trip-o-Link AND Lightning Arrester



Incorporating the famous Trip-o-Link with the new QR type Lightning Arrester results in a unit particularly well suited for rural line construction and maintenance.

The type QR Lightning Arrester is designed to channel the high impact pressure of lightning direct to the ground, *not* through various restricted passages. It reduces the extremely high melting temperatures that follow current arcs because expulsion is direct to atmosphere. Correct calibration is maintained for the service life of the arrester through the use of ring busses, rather than point-to-point electrodes.

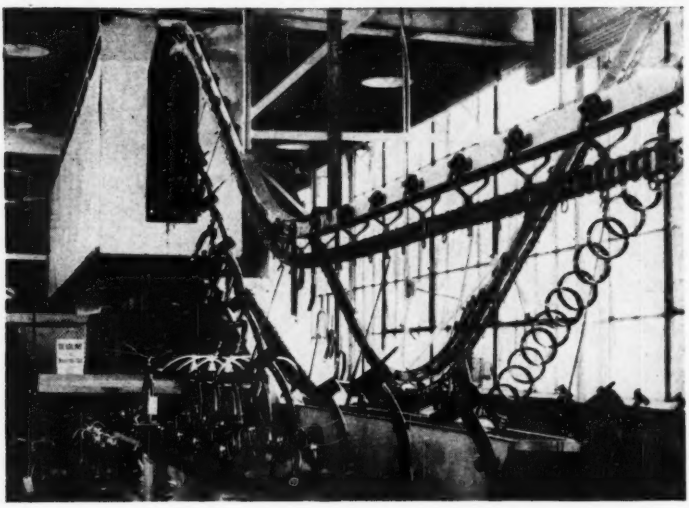
These advantages, plus the well-known performance features of the Trip-o-Link, give you full lightning, overload and short-circuit protection *all on one insulator*, thus conserving crossarm or pole space as well as installation time.

JAMES R. KEARNEY CORPORATION
4224-42 Clayton Avenue • St. Louis 10, Missouri
Canadian Plant: Guelph, Ontario

-128

Always Specify JAMES R. KEARNEY CORPORATION ST. LOUIS, MO. *for the Job . . .*

Better Construction – *SAFER* Maintenance



Consider INFRA-RED *for* LOAD-BUILDING

The near infrared process needs no introduction to the utilities. It is recognized as an outstanding load builder having a constant power factor. Utilities can recommend infrared lamp ovens as an economical source of heat without hesitancy, as lamps radiate between 85 and 90 percent as radiant energy compared to 60 percent for open type strip heaters.

Surprisingly, many Industrials are still unacquainted with the possibilities of infrared as a source of heat for such jobs as paint baking, dehydrating and preheating. Customer interest can best be incited by Power Sales Engineers since none of the Utilities are promoting sales of equipment for profit derived therefrom.

Customer advantages in using infrared include:

No stand-by heat loss.
Savings in floor space.
Savings in time over that of straight Convection type ovens.
No explosion hazard.
No maintenance problem.
Average lamp life 4000 hours which offers economical upkeep.
No licensed engineers required to operate ovens.

Jensen Specialties, Inc. can be of great help to Power Sales Engineers throughout the United States as we have Distributors and Manufacturer's Agents located in many strategic localities. These representatives are schooled in giving valuable assistance where needed in laying out oven baking and drying operations. In open territory, all inquiries are handled promptly direct from the factory.

Jensen Specialties, Inc. was the first oven manufacturer to introduce the "Dual Heat" principle. Another important feature of Jensen's ovens is the NESTING of the lamps, assuring even heat distribution. These two features plus the service policy of our Company have converted many a skeptic into an ardent enthusiast for infra-red equipment.

Another service that Jensens offer is complete responsibility for proper conveyor recommendations as we engineer and manufacture six different conveyors. Industrials much prefer to delegate authority for complete systems to one Company, rather than several.

Catalogs are available to all power Companies for distribution to Sales Engineers for handy reference.

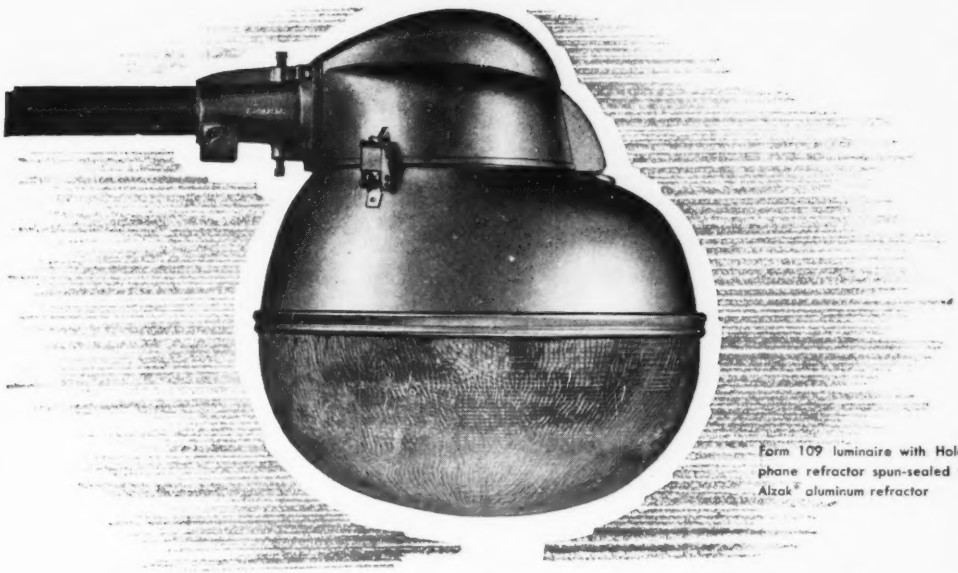
JENSEN SPECIALTIES, INC.

9339 FREELAND AVENUE
DETROIT 28, MICHIGAN

America's Foremost Designers and Builders of Infra-red Ovens, Conveyors & Paint Dip Tanks.

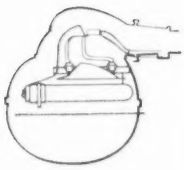
We believe this to be

—the most significant development in street lighting in 13 years!

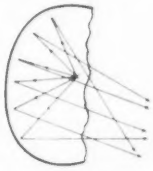


Form 109 luminaire with Holophane refractor spun-sealed to Alzak* aluminum refractor

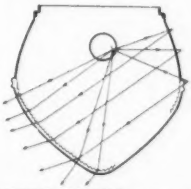
***Really* NEW** This is the first luminaire ever designed to take full advantage of the light produced by a horizontally burning mercury lamp—at the same time its uniformly lighted refractor produces more comfortable visibility.



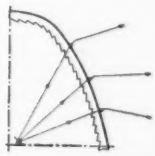
LAMP is placed high in the reflector to shield it from drivers. Arc-centering magnets assure full life from large mercury lamps when burned horizontally.



REFLECTOR has every square inch of its ovate surface carefully designed to direct the light downward and laterally in an asymmetric pattern. Reflected light passes around lamp for more efficient utilization.



LIFTING PRISMS accurately molded into the refractor lift the light sending it along the roadway. Vertical control restricts the candlepower above 72½ degrees on the driver approach sides for driver comfort.



TURNING PRISMS in the refractor redirect light from the house side of the luminaire into the roadway pattern. General Electric pioneered this reflector—prism combination for vertilateral control.

The Form 109 luminaire will burn the 10,000-lumen AH-5, 16,000-lumen EH-1, and 21,000-lumen FH-1 mercury lamps. Also, it can be adapted for large filament lamps—increasing, greatly, the possibilities of standardization. For details, ask for Bulletin GEA-5142. *Apparatus Dept., General Electric Co., Schenectady 5, N. Y.*

*Trade mark of the Aluminum Co. of America

More for Your Street-Lighting Dollar!

GENERAL ELECTRIC

New! Instant-starting

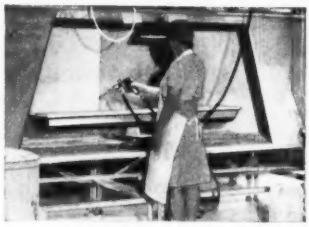
slimline fixtures

with wiring channels as well as reflectors available in Vitreous Porcelain Enamel

● Take a look at Wheeler Slimline Fixtures and you'll see the extra advantages that assure lowest cost in the long run. In addition to the benefits of instant-starting, you get the advantages of Wheeler "Skilled Lighting" design and construction . . . stable reflecting characteristics, easy cleaning, lower maintenance and extra-long service life. These inherent Wheeler features are the results of nearly 70 years of making quality lighting equipment.

Typical of Wheeler engineering thoroughness in Slimline Units is the exclusive auxiliary lamp support at center of fixture to prevent vibration of the 8-foot lamps. Fixture channel is in one sturdy piece . . . available in either baked enamel or porcelain enamel finish. Reflectors are in vitreous porcelain enamel finish only.

Two types of Slimline fixtures represent another Wheeler "Skilled Lighting" refinement. Each is designed for specific applications. Get all the facts on these latest products of Wheeler "Skilled Lighting". Write to **Wheeler Reflector Company, 275 Congress St., Boston 10, Massachusetts.**



NEARLY 70 YEARS OF "Skilled Lighting" Tradition

Here is one of Wheeler's many veteran workers . . . skillfully applying Wheeler's famous wear-resistant vitreous porcelain enamel surface to the inside of a reflector. Through her faithful adherence to high quality standards, she helps to maintain the distinguished Wheeler tradition of top value in modern industrial lighting.

See all our new 1949 units at Booth Nos. 63 and 64 at the International Lighting Exposition.

Industrial Slimline Unit End view of Industrial Type unit showing flat top. These units are designed for general industrial use under normal atmospheric conditions.

Textile Slimline Unit End view of Textile Type unit showing peaked top especially designed to eliminate frequent cleanings and danger of moisture damage.

Distributed Exclusively through Electrical Wholesalers

Wheeler REFLECTORS

SKILLED LIGHTING

MADE BY SPECIALISTS IN LIGHTING EQUIPMENT SINCE 1881

FOR MORE THAN *46 Years*

Century ELECTRIC

Has Devoted Its Effort to One Purpose—

To Build Better Electric Motors and Generators to Meet Industry's Needs

During these years of tremendous industrial growth, thousands of alert, progressive users and manufacturers have selected Century motors to power their production machines and appliances.

Century C MOTORS

The development of Century motors has kept pace with industry's demand for better, sturdier motors to definitely meet the constantly increasing multitude of applications.

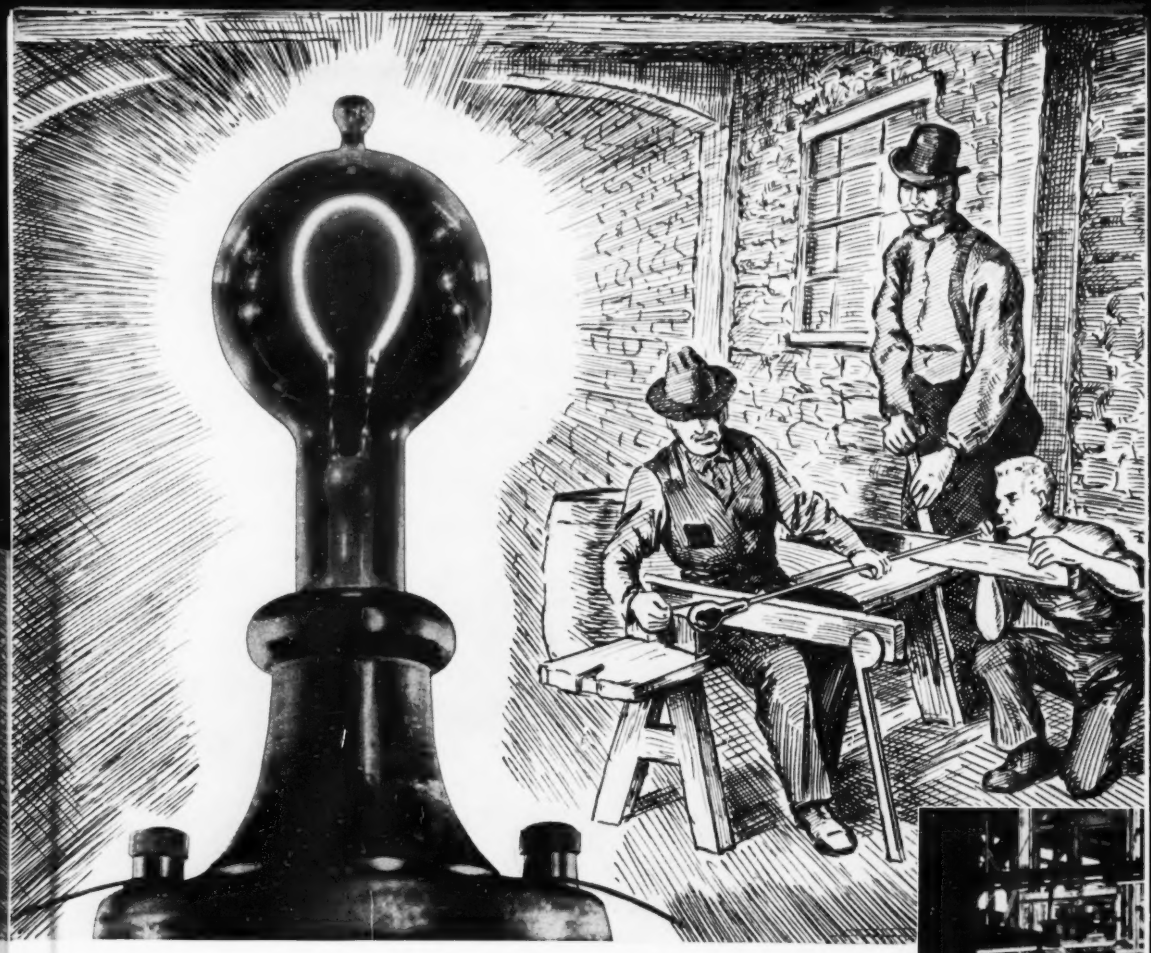
Today, the complete line of Century motors includes sizes from 1/6 to 400 horsepower—single phase, polyphase and direct current—in a wide range of kinds and types.

These Century motors are contributing to better manufacturing and better living through greater comfort, safety and economy.

-626

CENTURY ELECTRIC COMPANY 1806 Pine St., St. Louis 3, Missouri

Offices and Stock Points in Principal Cities

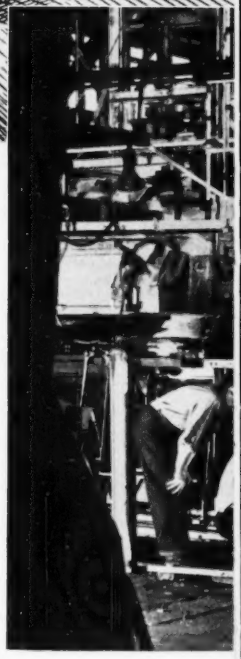


Glass that makes and controls light

In 1879, when Thomas Edison asked Corning to make a glass bulb to surround the filament of his new electric lamp, Corning Glass Works became a partner in building the power load. This episode marked the first in a long series of glass developments which utilized electric power in industry and home.

Today, automatic machines designed by Corning make most of the light bulb envelopes used in this country. Miles and miles of Corning exhaust tubing are used in the final stages of bulb assembly.

Corning's colored neon tubing and clear neon tubing coated by independent manufacturers light up Main Street, U.S.A. Miles of tubing for fluorescent and cold cathode lamps are drawn continuously by Corning every day. Corning glass helps light the nation.

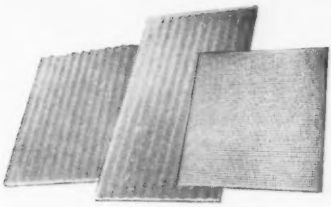


One of several Corning ribbon machines, each of which can make over 600 light bulb envelopes per minute.

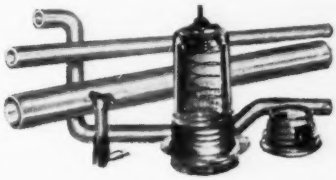
For years Corning technicians have been developing special glasses to control light by means of better transmission, diffusion, and concentration. Out of this has come glass for signalware, X-ray, black light and television as well as better industrial and home lighting.

Opalescent globe-ware, IES type shades, prismatic enclosing globes are in common use today. In MONA-LITE, ALBA-LITE, and just recently, FOTA-LITE, Corning offers the lighting engineer opal glasses to control light from fluorescent sources. Corning Lens Panels and PYREX brand Lenslites enable him to concentrate light where it is desired from either fluorescent or incandescent light sources.

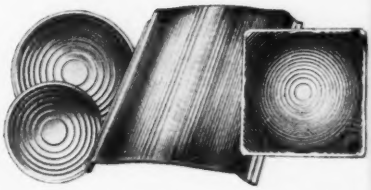
Thus, in the field of lighting alone, Corning has made many notable contributions to the progress of the "electrical world." Besides these, Corning glasses have been used in countless ways in the field of electronics. With this background of experience, Corning not only provides the glass that makes light but enables you to control it efficiently at low cost. If you are a lighting engineer or are interested in building the power load through lighting, ask for Corning's new manual, "Engineered Lightingware," Bulletin LS-17.



For diffusing fluorescent light Corning offers such opal glasses as MONA-LITE, ALBA-LITE, and FOTA-LITE—the latter features sealed-in louvers for smooth easy to clean surface.

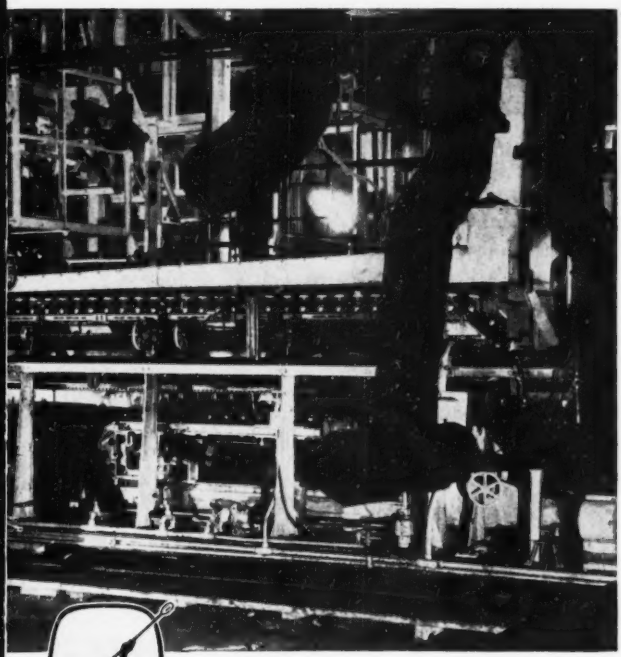


Thousands of PYREX brand insulators and miles of neon, fluorescent and cold cathode tubing are produced by Corning Glass Works every year.



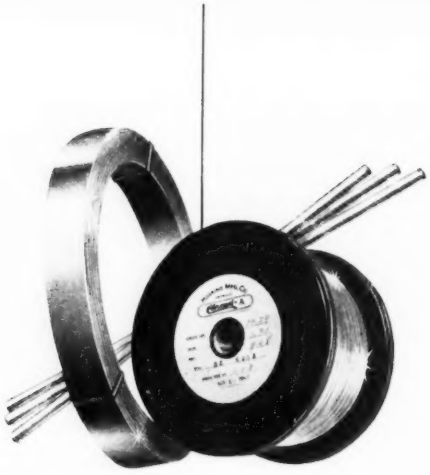
Corning curved and flat Lens Panels and PYREX brand Lenslites are used to control light from fluorescent and incandescent light sources.

Globe-ware, IES type shades and prismatic enclosing globes are widely used in industry and home.



CORNING GLASS WORKS

CORNING, NEW YORK



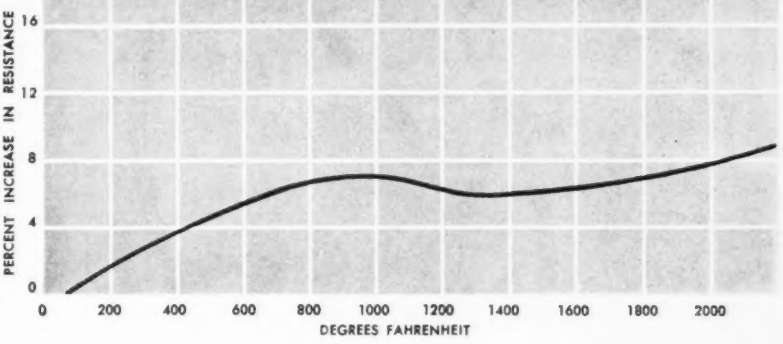
HOSKINS Chromel

Who'd have thought, some forty years ago, that electric heat would ever be used to do so many useful jobs . . . in nearly every home, in nearly every industry? One man who did was the founder of Hoskins. He'd spent years searching for a combination of metals that would make electrical heating practical. An alloy that would resist the passage of electricity . . . get hot, . . . and at the same time be highly resistant to oxidation . . . last a long, long time. He found his alloy in 1906 . . . one part chromium, four parts nickel. He called it CHROMEL. Since that time, many improvements have been made in processing the alloy for electrical heating applications . . . developments that have made it last many times longer and behave much better. But it's interesting to note that, despite continuing research here at Hoskins and throughout the world, no basic changes have ever been found that would improve upon the original CHROMEL formula.

No wonder, then, CHROMEL is called the basic element of electrical heating.

HOSKINS MANUFACTURING

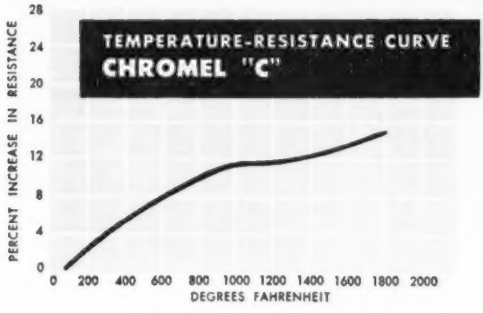
TEMPERATURE-RESISTANCE CURVE
CHROMEL "A"



CHROMEL A—The original 80-20 nickel-chromium resistance alloy. Possesses close-to-constant "hot" resistance between 700° and 2000° F., delivers full rated power throughout its long and useful life. Particularly recommended wherever heating elements must withstand adverse operating conditions . . . ranges furnaces, radiant heaters, etc. Resistivity: 650 ohms per circular mil foot at 68° F.

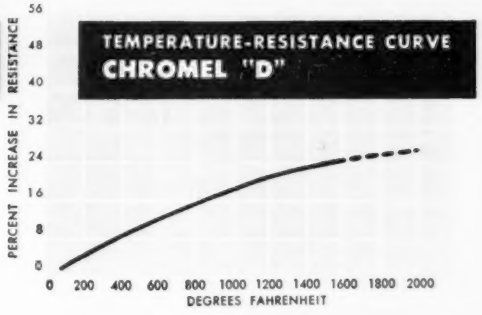
. . . the nickel-chromium resistance alloy that first made electrical heating practical

TEMPERATURE-RESISTANCE CURVE
CHROMEL "C"



CHROMEL C—A 60-16 nickel-chromium-iron alloy. Developed to meet the requirements of milder applications not exceeding 1700° F. . . . ovens, economy cookers, percolators, irons, as well as resistors and rheostats. Excellent for developing high resistances within a small space. Resistivity: 675 ohms per circular mil foot at 68° F.

TEMPERATURE-RESISTANCE CURVE
CHROMEL "D"



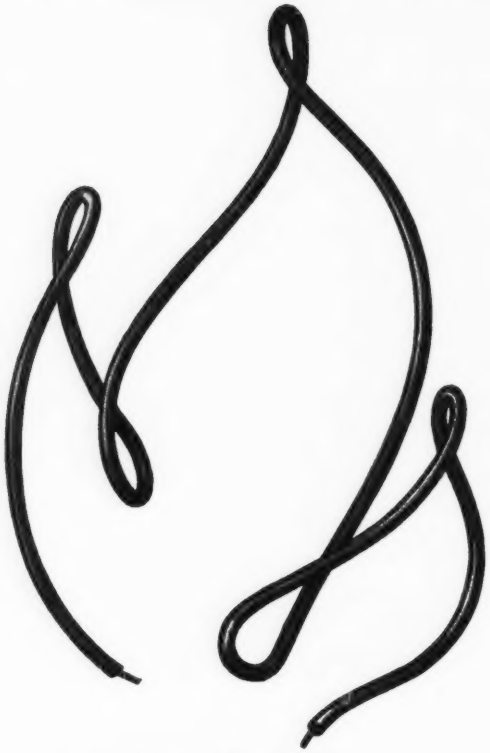
CHROMEL D—A 35-18.5 nickel-chromium-iron type alloy. While similar to the common heat-resistant alloys used for mechanical purposes, CHROMEL-D has been developed to a point which permits its use on many lower temperature resistance heating applications up to 1400° F. Resistivity: 600 ohms per circular mil foot at 68° F.

Whatever your interest in electrical heating, it pays to *know* Hoskins CHROMEL. Our Catalog M-1 tells the complete technical story . . . want a copy?

COMPANY

4445 LAWTON AVENUE • DETROIT 8, MICHIGAN

Chromel® nickel-chromium wire



IS YOUR NEW DESIGN HOT IN MORE WAYS THAN ONE?

New designs in radio, television and electrical appliances call for resistance to higher temperatures. . . . And here's just the wire to make connections wherever higher ambient temperatures must be met.

It is Intelin IN-108—product of the Selenium-Intelin Division of Federal Telephone and Radio Corporation. Its insulation, developed by Federal, is based on VINYLITE Brand Plastics.

This construction has received Underwriters' Laboratories approval for operation at 90° C.

Economical VINYLITE Brand Plastic insulation materials are bringing many other equally spectacular advantages to wire and cable users. They provide thinner walls, saving space and, of course, weight. All types are highly resistant to abrasion, to most chemicals, to grease, oil, alkalis, moisture and sunlight.

Even at low temperatures, VINYLITE Plastics are inherently flexible. Either non-flammable or slow-burning types are available. Write Department ES-28 for full information. Ask for the informative booklet entitled: "VINYLITE Plastic Wire and Cable Compounds."

Vinylite BRAND PLASTICS

BAKELITE CORPORATION

BAKELITE CORPORATION, *Unit of Union Carbide and Carbon Corporation* UCC 30 East 42nd Street, New York 17, N. Y.

Get THE MOST FROM LIGHT....

WITH PITTSBURGH PERMAFLECTOR LIGHTING EQUIPMENT

Maintain your creative freedom with Pittsburgh Permaflector Lighting Equipment . . . the line made in modules of related units that may be combined to form the design patterns, illuminating effects and foot-candle levels required to do an outstanding job. "Standard" Pittsburgh Permaflector Fluorescent and Incandescent Units give "the light you want where you want it" efficiently and economically.

"A PERMAFLECTOR PORTRAIT"
NETBOY'S - Evanston, Ill.
S. H. Morris & Associates - Architects

"Pittsburgh" Permaflector

FOR MORE KNOW-HOW ON "CUSTOM LIGHTING" WITH STANDARD EQUIPMENT

Write for Catalogs 48 and 46 which give application ideas, descriptions, specifications and other data about flexible Pittsburgh Permaflector Lighting Equipment.

PITTSBURGH REFLECTOR COMPANY

408 OLIVER BUILDING • PITTSBURGH 22, PENNSYLVANIA

MANUFACTURERS OF FLUORESCENT & INCANDESCENT LIGHTING EQUIPMENT

Permaflector Lighting Engineers in All Principal Cities

PITTSBURGH PERMAFLECTOR LIGHTING EQUIPMENT IS DISTRIBUTED BY BETTER ELECTRICAL WHOLESALERS EVERYWHERE

the NEW Trend in lighting!

LOUVERALL LIGHTING WITH LUMINOUS VINYLITE LOUVERS CREATES A NEW EXPERIENCE IN SEEING!

The trend not only is unmistakably to louvered ceilings of light . . . but to ceilings with LUMINOUS LOUVERS!

When you experience the lighting effect achieved with luminous louvers it's not hard to understand why those who *see* it, so overwhelmingly *prefer* it!

The secret of "Sky-Glo's" superiority is in its exclusive Vinylite (plastic) louvers which not only reflect light but also transmit light.* Thus "Sky-Glo" provides a translucent ceiling that not only affords a means of obtaining more light without annoying glare but actually offers a new experience in seeing!

"Sky-Glo" makes possible these high levels of illumination (in range of 50 to 150 footcandles) with exceptional low brightness (less than 1 footcandle per sq. in.). The result: a soft glareless illumination that makes seeing easy; that creates a restful yet stimulating atmosphere; that makes one completely unaware, visually and psychologically, of the high levels of illumination that are responsible for this "new experience in seeing."

Translucent "Sky-Glo" louvers heighten the beauty of the ceiling and add a scintillating and harmonizing note to the entire decorative scheme. Add to these exclusive advantages of "Sky-Glo" all of the many conventional advantages of the louverall lighting system and you can see why the new trend in lighting is so definitely to Benjamin "Sky-Glo."

BENJAMIN ELECTRIC MFG. CO., Dept. K, Des Plaines, Illinois

*Reflection Factor is 19%.
Transmission Factor is 71%.

Broadway Florist Shop, 218 W. Fifth St., Los Angeles, Calif.: *Sales Area For Florist Shop. Peter Telegin, Consulting Engineer with Basso and Riddel, General Contractor, Keith Electric Co., Electrical Contractor.*

Victor Adding Machine Company, 3900 N. Rockwell St., Chicago, Ill.: *Private Office. Olsen and Urbain, Architects; Chicago; Neiler, Rick, Bladen, Consulting Engineers; Henry Erickson, Chicago, General Contractor; Hoffman Electric Co., Chicago, Electrical Contractor.*

Stetson Shoe Store, Pittsburgh, Pa.: *Shoe Store Sales Area. John Schurke, Pittsburgh, Designer; Wood Electric Construction Co., Pittsburgh, Electrical Contractor.*

"Sky-Glo" Lighting Manual Available FREE to Illuminating Engineers

For complete story and data on one of the most significant developments in fluorescent lighting history in terms of lighting performance, applications, modernization and maintenance, write for your complimentary copy of Bulletin "SG."

BENJAMIN TRADE MARK

"Sky-Glo"

LUMINOUS LOUVERED LIGHTING SYSTEM

Distributed Exclusively Through Electrical Wholesalers

R-3124B

Do *Your* "20 Amp." Circuit Breakers Carry 20 Amps. Continuously?

UL LISTED UNDER RECOGNITION SERVICE UNDERWRITERS' LABORATORIES, INC.

Even in

COMPACT PANEL BOXES?

OVERHEATED ROOMS?

DIRECT SUNLIGHT?

NOT if they trip by Thermal Elements!

Insist on Murray FULLY MAGNETIC Circuit Breakers...

NO Thermal Element	**ALWAYS** Carry Rated Load Continuously
NOT Affected by Heat	**ALWAYS** Carry Harmless Temporary Overloads
NO False Tripping	**ALWAYS** Trip Instantly on Dangerous Overloads
NEVER Need "Derating"	**ALWAYS** Can Be Reset Immediately After the Overload Passes

This 8 circuit load center comes with 4, 6 or 8 Murray *Fully Magnetic* Breakers. Also available are 2 circuit and 4 circuit load centers.

Single pole breakers in 10, 15, 20, 25, 30, 35 and 50 amp. ratings. Only two handle positions — Off and On.

Each breaker can be *individually* replaced with breaker of same, lower or higher rating.

Get the full facts on Murray *Fully Magnetic* Circuit Breakers. Operating characteristics and construction features are given in this informative folder. Write for your copy *now*.

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Equip Today!

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SERVICE ENTRANCE & METER EQUIPMENT • MAGNETIC CIRCUIT BREAKERS
SWITCHES • CURRENT LIMITING REACTORS • CROWS NEST AERIAL LADDERS

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. . and we're referring to electrical products, of course — you are certainly in the majority among thoughtful purchasing agents and specification writers. Yes — most men whose job is to buy products for maximum engineering results invariably specify MACALLEN MICA — not just plain mica. They know that MACALLEN means dependability, uniformity, and assurance that their products will not fail to perform as designed, so far as insulation quality is concerned. The MACALLEN MICA habit grows on many firms who grow big because of common-sense in buying.

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Don't limit your mica specifications to forms you know about. Specify the shape, thickness and size that will do the job — MACALLEN will probably have it, or can process it for you.

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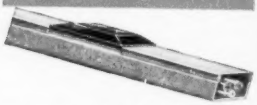
You can PLUGMOLD this room by 3 methods

unwired PLUGMOLD



Provides complete flexibility. Wiring is done on the job . . . outlets may be placed where needed . . . easily added or relocated. *Approved with devices* in place for three No. 12 or No. 14 conductors.

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Factory-wired, ready to install. Available in 3-foot lengths, 6 outlets on 6-inch centers . . . 6-foot lengths, 4 outlets on 18-inch centers.

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Outlet convenience by the yard! Coils of prewired receptacles, ready for quick installation. Available in four popular lengths, with brown or ivory receptacles.

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CUSTOMER SERVICE COUNTER-DESK

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IT'S FIRE PROTECTED!—Designed and built to provide utmost efficiency and operating convenience *plus certified fire protection for its contents*, the Customer Service Counter-Desk combines the usual Cashier's Counter, Fire-resistive Safe and Customer Contact Desk *into one compact unit* . . . providing ample housing space for *all* Service Orders, Customer History Records, Service Location Records, Meter History and Test Data, Ledgers, Cash Coupons, Meter Books and Cash Drawer.

The 72" x 42" desk top may be used for accounting and bookkeeping operations while the counter portion provides ample space for customers to fill out applications, checks or necessary forms.

IT'S PORTABLE!—Unlike customary permanent counters, the Counter-Desk saves space and can be moved about within the office or to a new location without costly alteration charges. Resplendent in Gray-Rite finish, the Customer Service Counter-Desk will add to the appearance of any office.

For detailed information, call our nearest office or write Systems Division, 315 Fourth Avenue, New York 10, N.Y.

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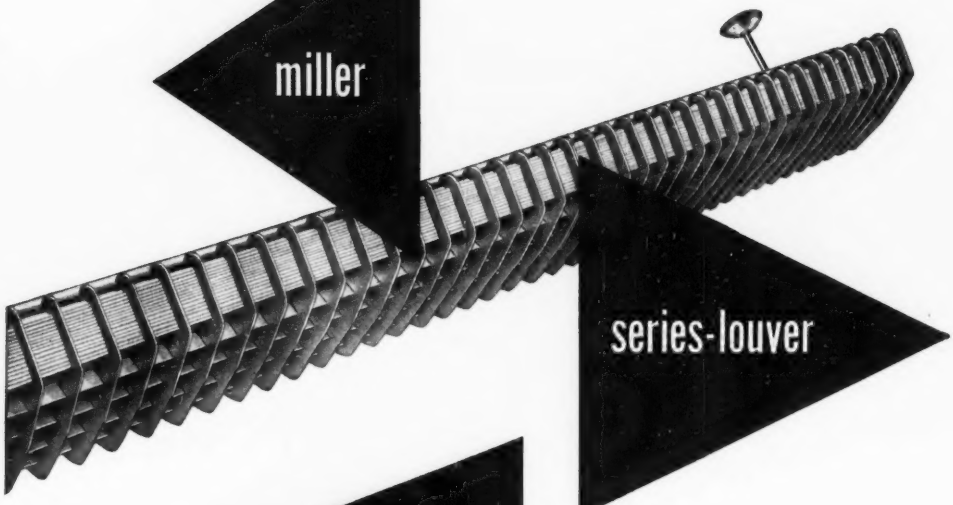

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a new high in lighting

New flexibility of application
of the 96 in. slimline fluorescent lamp.
New simplified installation,
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3

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STEP UP PRODUCTION WITH *Better Lighting*

APPLETON LIGHTING EQUIPMENT

Look to Appleton Lighting Equipment for maximum lighting efficiency at minimum installation, service and operating expense —whatever the illuminating requirement, whether indoors or out.

Now including the famous line of lighting fixtures formerly manufactured by the Goodrich Electric Company, Appleton Lighting Equipment is your unified and convenient source of supply and information for virtually any industrial lighting need. Complete in every phase, the Appleton line is expertly engineered and machined—precision-manufactured with the highest quality materials.

Appleton Lighting Equipment is designed to utilize the lamp's full intensity, minimize glare and provide the illumination necessary for best possible working conditions. Whatever the required intensity, whatever the area to be illuminated, you'll find the fixture you need with the type of mounting required in the Appleton Line.

Make the Appleton Catalog your convenient buying guide. Fully detailed and graphically illustrated, an Appleton Catalog will be mailed to you immediately upon request. Be sure to have one and use it for faster, easier—completely dependable purchasing of all lighting and electrical equipment.

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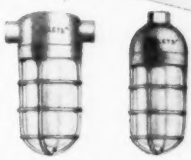
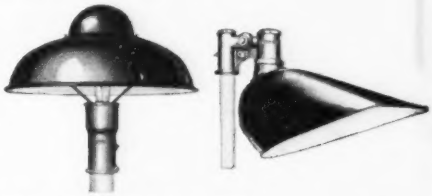


FOR HAZARDOUS LOCATIONS

Appleton—makers of the *FIRST* Explosion-Proof Fluorescent Lighting Fixture—offers numerous types and combinations of dependable Explosion-Proof Fixtures. Dust-Tight and Vapor-Tight Fixtures, too, in a variety of types and sizes to meet your requirements.



OUTDOOR ILLUMINATION AT ITS BEST

The famous Appleton "Goodrich" Standlite and No. 95 Floodlight brings day-like illumination to service stations, parking areas, athletic fields. Easily maintained, designed to bring better business.

THE APPLETON "GOODRICH" STOCKLITE diffuses light from eight different reflecting surfaces, adequately illuminating narrow stock aisle shelves and bins.

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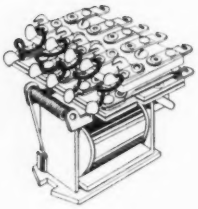
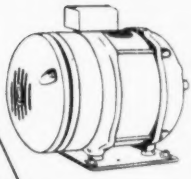
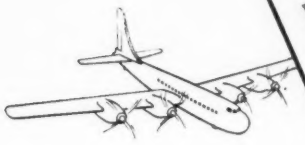
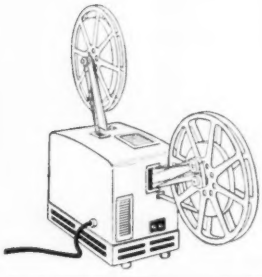


WANTED
Tough Insulation Problems







Put BH Fiberglas Sleeving or Tubing to work on tough insulation problems in your product or plant equipment and eliminate the possibilities of insulation breakdown. Whether the problem is excessive current load, vibration, extreme temperatures, greases, oils or moisture — or when flexibility is essential — there is a BH product to solve it. Write for samples for laboratory and production testing. Include a few facts about your product, requirements, voltages and temperatures encountered. Let BH Fiberglas insulations do a better job for you.

BENTLEY, HARRIS MFG. CO., CONSHOHOCKEN, PA.

BH EXTRA FLEXIBLE FIBERGLAS SLEEVING

Remarkably flexible because no hardening varnish is used. Cuts without fraying and is non-combustible. Available in all colors. Basic sleeving withstands heat to 1200°F. Color unaffected up to 300°F.

BH SPECIAL TREATED FIBERGLAS SLEEVING

Heat resistant to 1200°F. Cuts cleanly without fraying and is tubular for ease of installation. Maximum flexibility. Unsaturated. Can be furnished double-braided or extra heavy wall to meet special conditions. Supplied in natural color.

BEN HAR SPECIAL TREATED FIBERGLAS TUBING

Available in Grade A — 7000V. and Grade B — 4000V. Flexibility combined with toughness. You can knot it, twist it, or pound it with a rawhide mallet. There's no loss of dielectric strength. Non-fogging. Non-corrosive.

OTHER BH PRODUCTS

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BH *Fiberglas** SLEEVINGS

*BH Non-Fraying Fiberglas Sleevings are made by an exclusive Bentley, Harris process (U. S. Pat. No. 2303530). "Fiberglas" is Reg. TM of Owens-Corning Fiberglas Corp.

USE COUPON NOW

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I am interested in BH Non-Fraying Fiberglas Sleeving _____ for (size or I.D.) _____ (product) operating at temperatures of ____°F. at ____ volts. Send samples so I can see how BH Fiberglas Sleeving stays flexible as string, will not crack when bent.

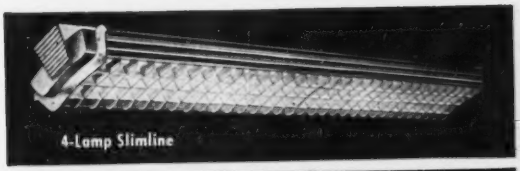
NAME _____ COMPANY _____

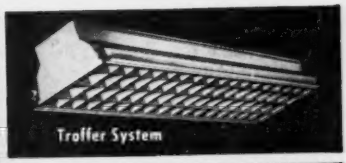
ADDRESS _____

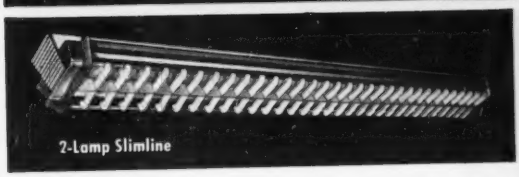
Send samples, pamphlet and prices on other BH Products as follows:

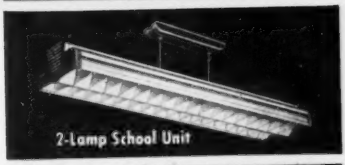
☐ Cotton or Rayon-base Sleeving and Tubing

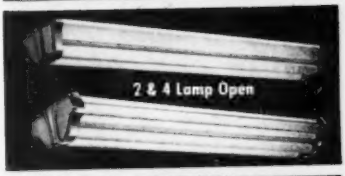
☐ Ben-Har Special Treated Fiberglas Tubing











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in the MITCHELL COMPLETE LIGHTING LINE!

Build your lighting business *profitably* around the *one complete line* that covers your entire market. The MITCHELL Line—now well over the 150-model mark—is the most complete and diversified in the industry. This progressive development of "in demand" preferred quality merchandise, priced for profitable volume sales, gives you a powerful selling "edge." Here are your MITCHELL merchandising advantages:

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2. **An ever-growing line that helps you grow**
3. **Strong acceptance in the lighting field**
4. **High saleability — competitive price — Guaranteed standards of quality**

It's good business to concentrate your selling program around MITCHELL—the *complete lighting line* that builds solid business and bigger sales for you.

YOU'LL SELL THEM ALL

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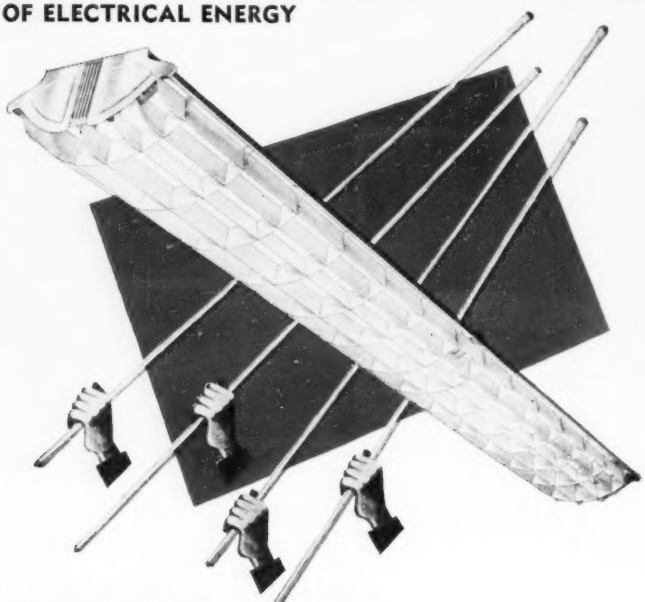
First Choice in Lighting • The Pioneer Line that Keeps Growing

ANOTHER GUTH CONTRIBUTION TO INCREASED USE OF ELECTRICAL ENERGY



SLIMLINE LAMPS
and
GUTH SLIMLINE TRUCOLITE*
the winning team

The only **Slimline** fixture with downlight reflectors for maximum benefit from the new lamps. Greatest light-producer—sleek appearance. Easy to handle. One man can install it. Simplified wiring. Immediate delivery.

Versatile! For 2 or 4 lamps—open, with eggcrate louvres, or glass diffusers—mounted flush or suspended, in units or rows. For 200, 300 and 425 m.a. lamp intensities.

Cash in on the profit-packed **Slimline** advertising—send for Bulletin 852-H from

Guth LIGHTING

YOUR TEAMMATE IN *precision-planned* LIGHTING

THE EDWIN F. GUTH COMPANY / ST. LOUIS 3, MISSOURI

*Ⓡ—U. S. Patent Nos. 122586, 2331774

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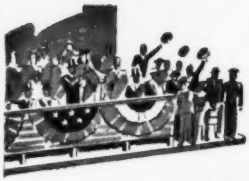
Leaders in Lighting since 1902



F-15A

HERE'S A

Parade

YOU WON'T WANT TO MISS...

Everybody loves a parade but here's one that's particularly interesting to YOU because it's packed with "pocket-book" appeal. It's a never-ending parade of products and services designed to help you do *your* job better, quicker and cheaper. You're in the "reviewing stand" for this parade because it comes to you in the advertising pages of every issue of this magazine. Alert manufacturers use these advertising pages to get the *news* about their products and services to *you*... quickly and effectively. To be well-informed about the latest developments in *your* industry... and to stay well-informed... *read all the ads too.*

McGRAW-HILL PUBLICATIONS

HEADQUARTERS FOR INDUSTRIAL INFORMATION

800 ohms/cmf

Temp. Coeff. of Resistance:
± 0.00002 max. from −50°c to +100°c

Karma

the improved electrical resistance alloy!

Higher Ohmage makes possible Smaller Resistors—Increased Savings

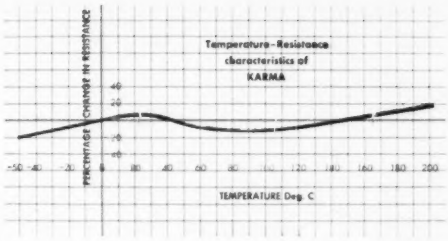
Compared with Manganin and Constantan (Advance*), the copper-base alloys widely used for high accuracy wire-wound resistors, the electrical resistivity of Karma* is exceptional — 800 ohms per circular mil foot, at 20°C, it is more than 2.7 times greater. Now you can wind even smaller precision resistors at still lower cost per ohm.

More Stable Resistance permits Wider Applications—at Wider Temperature Ranges

The comparably Low Temperature Coefficient of Resistance of Karma remains constant over a very much wider temperature range than that of Manganin or Constantan (Advance*). The "useful range" of Karma is more than 8 times that of Manganin and 4 times that of Constantan (Advance*). Karma, therefore, is especially adapted for service in precision resistors that are subjected to severe changes in temperature.

Low Thermal EMF Value against Copper assures Extreme Accuracy

In cases where error due to voltage generated by thermal EMF against copper must be confined to negligible proportions, Manganin has long been accepted as ideal for resistor windings. The thermal EMF value for Karma against copper is equal to that of Manganin itself!



High Resistance to Oxidation prolongs Electrical Properties

The superior surface oxidation resistance of Karma, essentially a nickel chromium alloy, enables it to retain its fine electrical properties longer than the copper-base alloys Manganin and Constantan (Advance*).

Higher Tensile Strength permits Faster Winding Speeds — saves Production Time

In addition to its outstanding electrical qualities, Karma affords physical advantages over the commonly accepted alloys. Its higher tensile strength permits faster winding speeds; its lower thermal expansion minimizes distortion and movement in windings.

In a word, this urgently needed Driver-Harris alloy offers *plus values all along the line*. Ask us about it. We shall be glad to supply you with complete data.

50TH YEAR — SPECIAL PURPOSE ALLOYS SINCE 1899 — D H — TRADE MARK REG. U.S. PAT. OFF. — 1899 - 1949

KARMA* is manufactured only by

Driver-Harris Company

HARRISON, NEW JERSEY

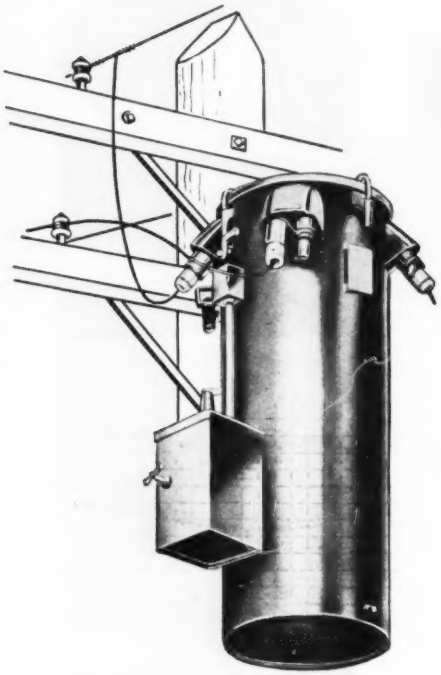
BRANCHES: Chicago, Detroit, Cleveland, Los Angeles, San Francisco, Seattle

Manufactured and sold in Canada by
The B. GREENING WIRE COMPANY, LTD., Hamilton, Ontario, Canada

*T.M. Reg.U.S.Pat.Off. *Formerly D-H experimental alloy #331

YOU CAN BE **SURE**.. IF IT'S

Westinghouse



CUTS INSTALLATION TIME

66%

The New Westinghouse Type CSP-C Packaged Unit Regulator saves time and money. It's complete in a single package . . . no lightning arresters, no primary fuse cutouts or oil switches, and no protective relay to install separately. All are contained in this completely self-protected packaged unit regulator.

There is only one self-contained unit to install, in 3 easy steps:

1. **Hang the CSP-C "tub" on the pole.**
2. **Connect primary and secondary leads.**
3. **Connect the control line.**

Get the complete story. Send today for B-4190 to Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pa. J-04239

NEW

Constant Current Type CSP-C Street Lighting Regulator

●

Complete

In One Package

Westinghouse

PLANNED LIGHTING PAYS

To generate electricity for transmitting messages, the telegraph industry relied on batteries. Cells of the gravity battery were cumbersome jars — 12 in. high, 8 in. across. By 1893, finding space for thousands of jars threatened the industry's expansion. Crocker-Wheeler, oldest electric motor manufacturer, designed and built motor-generator sets. Each, occupying a space two ft. square, did the work of 500 of the old cells which took up more than 222 sq. ft.

When the Telegraph Industry escaped from GLASS JARS...

CROCKER-WHEELER
made motor news

TODAY, 55 years and over a million motors later, Crocker-Wheeler no longer concentrates on the design and manufacture of special motors exclusively. But the pioneering spirit and engineering skill of Crocker-Wheeler that persuaded industry to adopt electricity half a century ago are still very much alive—in the performance of C-W standard motors today.

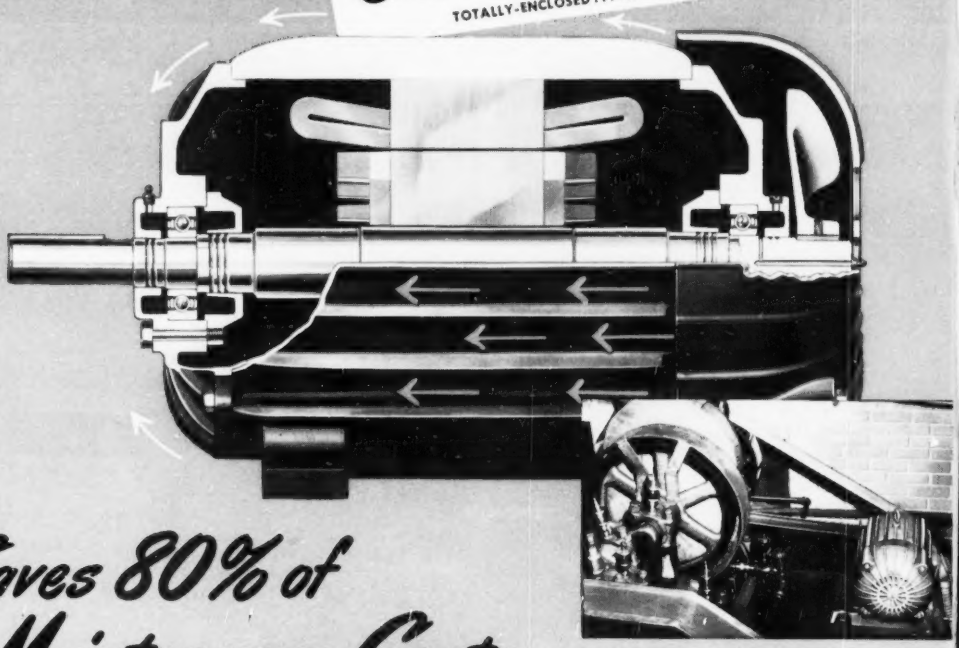
Past and present (yes, and the future) are inseparably fused at Crocker-Wheeler. A high percentage of the skilled workers who helped C-W make motor news through the years are still on the job, bringing to motor problems of modern industry a rare background of knowledge and engineering experience.

You'll understand what we mean (if you don't already know) as new, more efficient standard motors, developed by Crocker-Wheeler, are introduced in 1949. You can sense it just by *talking* to Crocker-Wheeler when you have a difficult motor problem. Here, you will say, is a master of the art of motor-making—but more than that, the kind of organization with which you would like to do business Crocker-Wheeler Electric Manufacturing Company, Ampere 3, N. J.

AND CROCKER-WHEELER IS MAKING MOTOR NEWS TODAY

CROCKER-WHEELER *Sealedpower* MOTOR

TOTALLY-ENCLOSED . . . FAN-COOLED



Saves 80% of Maintenance Costs

Sealedpower Motor driving a vertical triplex power pump where moisture is excessive.

You can make maintenance savings of 80% and *more* with Crocker-Wheeler Sealedpower Motors. The secret? C-W dollar-saving design. No other totally-enclosed, fan-cooled motor has *exterior* cooling, with the fan-driven airstream blowing over a finned frame, carrying dust and fumes *outside* and *away*. (The outside fins that identify a Sealedpower Motor provide over 150% more cooling surface.)

But that's not all — this motor keeps cooler longer because it keeps cleaner. There's no place for lint or dirt to *collect* . . . nothing to hold heat *in*. Even on the really dirty jobs, a Sealedpower Motor will keep production going many times longer than "ventilating passage" motors, without a shutdown for cleaning.

For years of cool, clean operation and low maintenance cost, specify Sealedpower Motors. They're stock motors made for the toughest service. In new ratings from 3 to 60 hp.

Crocker-Wheeler Electric Manufacturing Company, Ampere 3, N. J. Division of The Joshua Hendy Corp., Branch Offices: Boston, Buffalo, Chicago, Cincinnati, Cleveland, Los Angeles, Milwaukee, New York, Philadelphia, Pittsburgh, San Francisco, Washington, D. C. Representatives in principal cities.

SEND FOR BOOKLET, "It's Different — it's a Dollar-Saver." Tells why the Sealedpower Motor will save money for you.

WHATEVER YOUR MOTOR REQUIREMENTS — CALL ON CROCKER-WHEELER

If Crocker-Wheeler builds it, it's a better built machine.

Horizontal and Vertical Protected-Type Induction Motors

A-C Generators and High Speed Synchronous Motors

Large D-C Motors and Generators

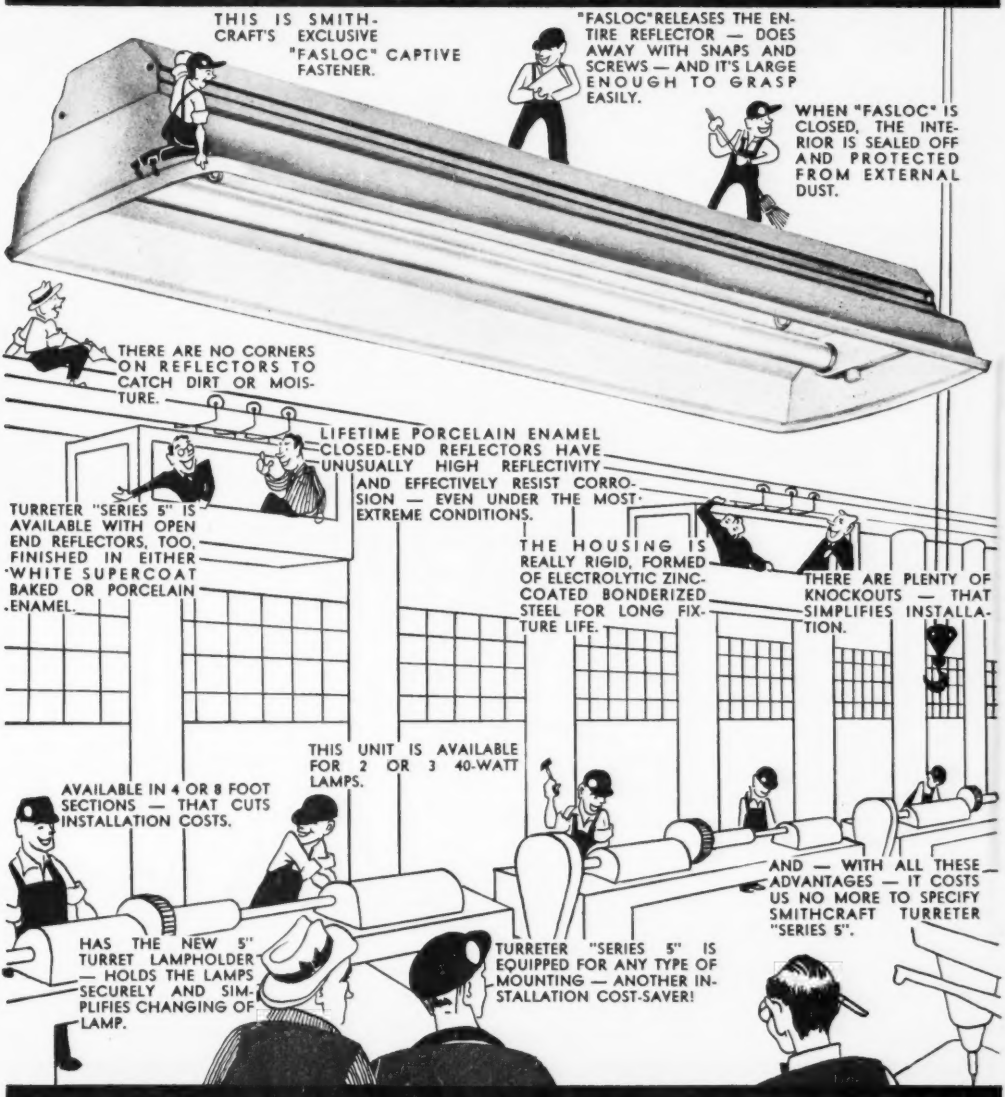
Turbogenerators

CROCKER WHEELER

ELECTRIC MANUFACTURING COMPANY, AMPERE 3, N. J.

Division of Joshua Hendy Corporation

this is the sensational NEW Smithcraft TURRETER "Series 5"


THIS IS SMITH-CRAFT'S EXCLUSIVE "FASLOC" CAPTIVE FASTENER.
"FASLOC" RELEASES THE ENTIRE REFLECTOR — DOES AWAY WITH SNAPS AND SCREWS — AND IT'S LARGE ENOUGH TO GRASP EASILY.
WHEN "FASLOC" IS CLOSED, THE INTERIOR IS SEALED OFF AND PROTECTED FROM EXTERNAL DUST.
THERE ARE NO CORNERS ON REFLECTORS TO CATCH DIRT OR MOISTURE.
LIFETIME PORCELAIN ENAMEL CLOSED-END REFLECTORS HAVE UNUSUALLY HIGH REFLECTIVITY AND EFFECTIVELY RESIST CORROSION — EVEN UNDER THE MOST EXTREME CONDITIONS.
TURRETER "SERIES 5" IS AVAILABLE WITH OPEN END REFLECTORS, TOO, FINISHED IN EITHER WHITE SUPERCOAT BAKED OR PORCELAIN ENAMEL.
THE HOUSING IS REALLY RIGID, FORMED OF ELECTROLYTIC ZINC-COATED BONDERIZED STEEL FOR LONG FIXTURE LIFE.
THERE ARE PLENTY OF KNOCKOUTS — THAT SIMPLIFIES INSTALLATION.
THIS UNIT IS AVAILABLE FOR 2 OR 3 40-WATT LAMPS.
AVAILABLE IN 4 OR 8 FOOT SECTIONS — THAT CUTS INSTALLATION COSTS.
AND — WITH ALL THESE ADVANTAGES — IT COSTS US NO MORE TO SPECIFY SMITHCRAFT TURRETER "SERIES 5".
HAS THE NEW 5" TURRET LAMPHOLDER — HOLDS THE LAMPS SECURELY AND SIMPLIFIES CHANGING OF LAMP.
TURRETER "SERIES 5" IS EQUIPPED FOR ANY TYPE OF MOUNTING — ANOTHER INSTALLATION COST-SAVER!

Turreter "Series 5" by Smithcraft is a heavy-duty industrial fixture, designed specifically to meet the most exacting industrial requirements. Low initial cost, simplified maintenance and installation, comfortable cut-off from lamp glare, high construction standards . . . these and many other exclusive Smithcraft fixtures are important reasons for specifying the Turreter "Series 5" — by Smithcraft, manufacturer of America's finest fluorescent fixtures.

Smithcraft
LIGHTING DIVISION
CHELSEA 50, MASSACHUSETTS

Tell your customers what users say about

GENERAL ELECTRIC AUTOMATIC BLANKETS

These are typical comments, unsolicited, from some of the nearly-a-million present-day users . . .

"I bought a General Electric Blanket last Christmas for my husband, and he liked it so very much he surprised me by buying one for me. We really do love them and have recently ordered two more for our two sons!" Mrs. F. N., Ill.

•

"I would like to tell the world about the comfort and pleasure of sleeping under a G-E Automatic Blanket. It takes the bite out of old man winter. And keeps the bed warm and cozy, regardless of the temperature. We would not part with ours for any consideration." H. W., Texas

•

"I received one of your Automatic Blankets as a Christmas present, and am enjoying it immensely." Mrs. E. B., Mass.

•

"I purchased a G-E Blanket about a month ago, and am enjoying it every night. I wonder, now, how we ever got along without one, especially in this climate." B. M., Minn.

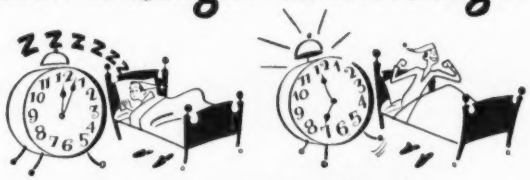
•

"My son gave me a blanket for Christmas, and it is fine! I sleep at the same warm temperature all the time, right through zero weather." Mrs. D. C., N. C.

•

"My uncle, 75, purchased an Automatic Blanket recently. He says his only regret is that he did not have one years ago. My son has also tried the blanket in his bedroom—a cold room—and was quite comfortable. No praise I could offer would be too much for the G-E Blanket!" Mrs. W. S., Virginia

From midnight to morning...



This load-builder's busy for you!

It's the General Electric Automatic Blanket! And look!...Two G-E Blankets are equal to the kilowatt-hour load of one average refrigerator!

During off-peak hours—when the town's fast asleep—General Electric's Automatic Blanket boosts your load.

That's why you'll want to promote this wonderful, warmth-without-weight covering! And right now is a good time to do it.

Why not begin right away by featuring Automatic Blankets as gifts? Easter, Mother's Day, Father's Day are coming up! And just in time for this big gift season, General Electric offers three De Luxe Automatic models—in addition to the standard line! A gift blanket that's *really luxurious* . . . bigger, more beautiful, and in a handsome gift box!

Nearly a million people are now sleeping under General Electric Automatic Blankets, and every day, letters pour in from users, praising this cozy, one-cover way to sleep!

And remember, every Automatic Blanket used in your town means *more off-peak load for you!* So get full details, including enthusiastic statements from leading utility executives, today. Write Appliance and Merchandise Dept., General Electric Company, Bridgeport 2, Connecticut.

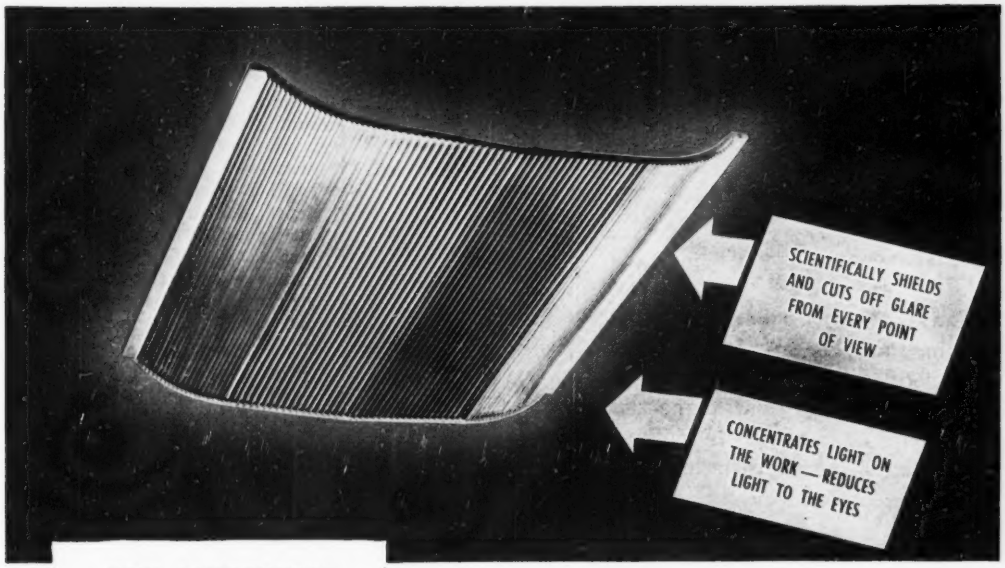
Automatic Blanket

"Goes to work when the lights go out"

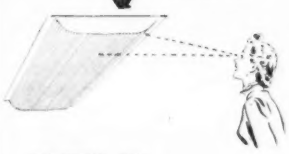
Approved by Underwriters' Laboratories, Inc.

GENERAL ELECTRIC

NEW HOLOPHANE CONTROLENS* Completely ELIMINATES GLARE from FLUORESCENT LIGHTING


SCIENTIFICALLY SHIELDS AND CUTS OFF GLARE FROM EVERY POINT OF VIEW
CONCENTRATES LIGHT ON THE WORK — REDUCES LIGHT TO THE EYES

NEW LENGTHWISE CONTROL



AS WELL AS CROSSWISE CONTROL

CUTS OFF GLARE COMPLETELY

This new CONTROLENS, is as attractive in appearance as it is highly efficient in performance. It adds a note of elegance to a lighted interior, and provides optimum visibility with comfort. Its new optical construction solves the glare problem. Light that would normally appear in the glare zone is routed to the work. Some light goes directly to the ceiling to reduce contrast between lens and background. This lens is remarkably light in weight without loss of strength or resistance to breakage. Precision-sawed to insure a close fit to adjacent lenses. There is no transverse flange to detract from the unbroken streamlined appearance of continuous runs.

Write for data on the new Holophane CONTROLENS today.

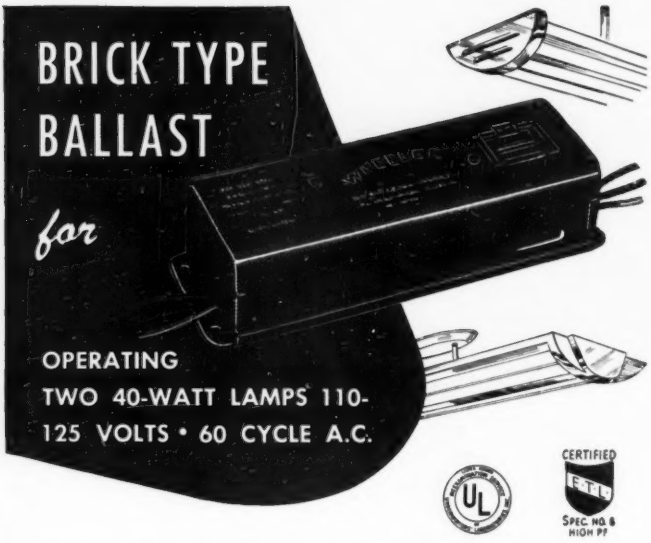
Holophane

*REG. U. S. PAT. OFF

HOLOPHANE COMPANY, Inc.

Lighting Authorities Since 1898 • 342 MADISON AVENUE, NEW YORK 17, N.Y.

THE HOLOPHANE COMPANY, LTD., THE QUEENSWAY, TORONTO 14, ONTARIO



Among Wheeler Ballasts for high power factor operation is the Brick Type — Catalog Number 241B — the result of good basic design and engineering applied to skilled manufacture and rigid testing and inspection. Like all Wheeler Ballasts, the Brick Type is built to maintain permanent electrical characteristics, tailored to the voltage and current requirements of the lamp — under both starting and operating conditions. Each ballast is matched to the lamp rating with which it will be used. This ballast is approved by both the Electrical Testing Laboratories and the Underwriters' Laboratories.

Wheeler high power factor Ballasts are offered for single and two lamp operation, in 15, 20, 30, 40 and 100 watt ratings, and for Slimline, two lamp, 200 M.A. and 300 M.A.

AVAILABLE SOON

WHEELER BALLASTS FOR OPERATING THE NEW 25 WATT LAMP AND THE NEW SLIMLINE 96T12 LAMP.

WRITE TODAY FOR COMPLETE BALLAST INFORMATION

THE WHEELER INSULATED WIRE CO., INC.

DIVISION OF THE SPERRY CORPORATION

1305 EAST AURORA STREET
WATERBURY 91, CONNECTICUT

MAGNET WIRE • COILS • COMMUNICATIONS EQUIPMENT

Fluorescent Lighting An Opportunity

February 11, 1939

". . . Each new electrical development finds opposition to its adoption and use. A case in point is the new fluorescent lighting. Here and there come the reports that are as old as history—it will reduce revenue, it will create bad power factor conditions. Instances are available where sales have been stopped because of these reports. . . . At present fluorescent lighting is in the embryonic stage. It is special and supplementary to other lighting. It has not reached technological or design maturity. But we should use it, develop it and help nurture it so that some time once again the industry may be able to cite a humanitarian contribution as well as one that brought increased revenues into being."

Promote Industry Unity

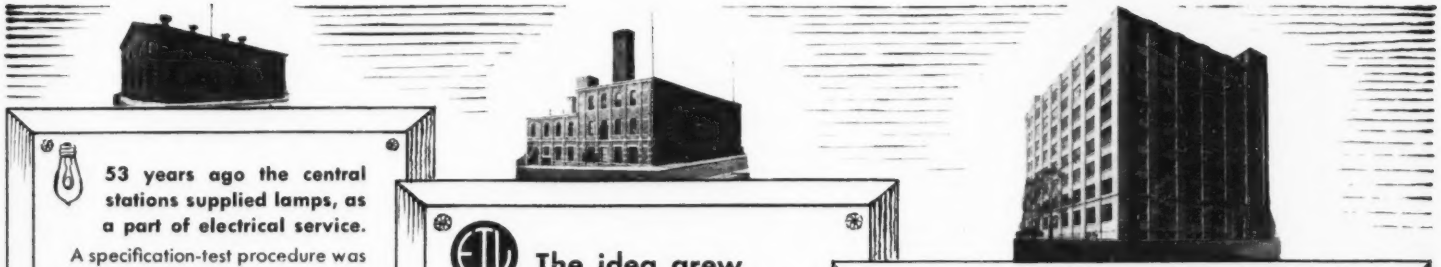
November 18, 1939

Too Much Distrust "Why is there so much mutual distrust throughout the electrical industry? . . . Jealousy, bickering, mistrust, hatred, aloofness have no place in a program of progress. We have a big job ahead of us to serve America with more electrical service at less cost, and without government interference. This is not the job of any one part of the industry alone; it is a job for all, working together. There's opportunity, profit and employment in working together. On the other hand, if we each insist on going our own sweet way we can rest assured that we will get no further than the tides of other business will take us."

Engineering Participation In Public Affairs

April 13, 1946

". . . Simply stated, engineers should be good citizens. Many are participating to the best of their ability in local affairs, but many more are not. Apparently they are waiting for some organization of engineers to assert itself so that they may feel they are having a special voice in national affairs."



53 years ago the central stations supplied lamps, as a part of electrical service.

A specification-test procedure was adopted.

ETL (in its plant above) supplied its testing facilities.

The customer was given good quality products.

The idea grew

The Central Station, intent upon good quality in generation and distribution to operate the customer's good quality product,

—used the services of **ETL** (in its enlarged plant above) to develop procedures in wires, cables, transformers, etc.

Manufacturers, intent upon good quality, cooperated.

35,561,839 of these issued last year

Thirty-five million good quality products are thus directed to provide customers with good quality electric service.

At **ETL** are many services you may call to your aid in

RESEARCH
ANALYSIS
INSPECTIONS
TESTING

just as though they were departments of your own business . . . more economically supplied.

Central Stations

took the lead to encourage
GOOD QUALITY in electrical applications

Electrical Testing Laboratories, Inc.

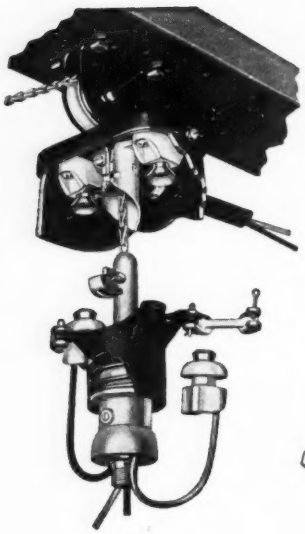
2 East End Avenue at 79th Street, New York 21, N. Y.

services to those intent upon

GOOD QUALITY

You can clean, maintain and relamp your High Bay Lighting Fixtures CHEAPER with Thompson Disconnecting and Lowering Hangers.

We invite you to use our engineering service.

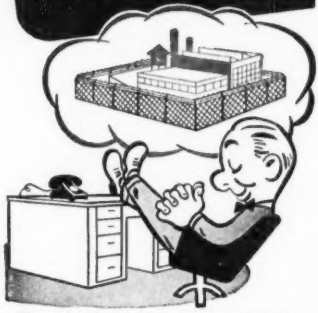


T·E

THOMPSON
DISCONNECTING & LOWERING
HANGERS

THE THOMPSON ELECTRIC CO.
1101 POWER AVENUE • CLEVELAND 14, OHIO

You can relax when your property is fenced by STEWART



No need to lose any sleep over vandals molesting your industrial property when it's surrounded by a Stewart Chain Link Wire Fence. fence framework makes it the heaviest and The All Beam construction of the Stewart strongest chain link wire fence manufactured. A Stewart Fence will give you the utmost in protection, and many years of dependable, low cost service. Write for Catalog No. 83.

THE STEWART IRON WORKS CO., INC.,
1666 Stewart Block Cincinnati 1, Ohio
Experts in Metal Fabrications since 1886

Stewart IRON and WIRE FENCES

STEEL STRAND

Crapo GALVANIZED PRODUCTS

ALL the strength and durability inherent in steel are combined—with definite economies—in *Crapo* Galvanized Steel Strand. Heavy, ductile, tightly-bonded zinc coatings, applied by the famous *Crapo* Galvanizing Process, provide lasting protection against corrosion.

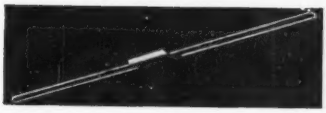
Ask the distributor of *Crapo* Galvanized Products near you or write direct for further information!

INDIANA STEEL & WIRE CO.
MUNCIE, INDIANA

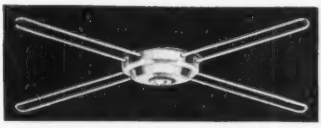
Originators-Pioneers-Leaders

in the design and development of

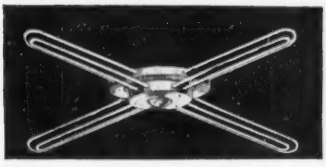
COLD CATHODE FIXTURES



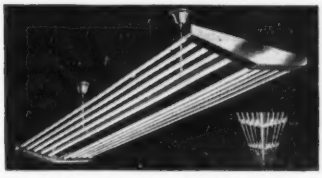
U-280 Lumeneer, Jr. Designed especially for us with the modern cold cathode hairpin lamps.



UX-480 Lightaleer, Jr. a four lamp unit for use with cold cathode hairpin lamps.



UX-880 Lightaleer, Sr. an eight lamp unit designed for cold cathode hairpin lamps.



IEC—1080 Moderneer designed for use with ten 96" slimline lamps or ten 93" cold cathode lamps. This represents one of our group of slimline models available in single fixtures or continuous runs.

● After years of intensive study and exhaustive experimental work Illuminating Engineering was the first to design and market a modern 8 foot long lighting fixture which would take either a SLIM-LINE or COLD CATHODE FIXTURE.

Illuminating Engineering Company was also instrumental in introducing the HAIRPINLINE *(Cold Cathode) type of lighting to the public. This fixture being especially developed for school room applications.

With these fixtures now available for all types of commercial installations we are adhering to the growing demand for LOW SURFACE BRIGHTNESS sources, plus minimum operating troubles—MUCH LONGER LAMP LIFE — better lighting distribution—and ease of installation. For example in school room installations involving more than 16,000 lamps, there was less than 1% replacement over an average period of three years.

This is typical of the economy recorded by cold cathode lighting wherever installed.

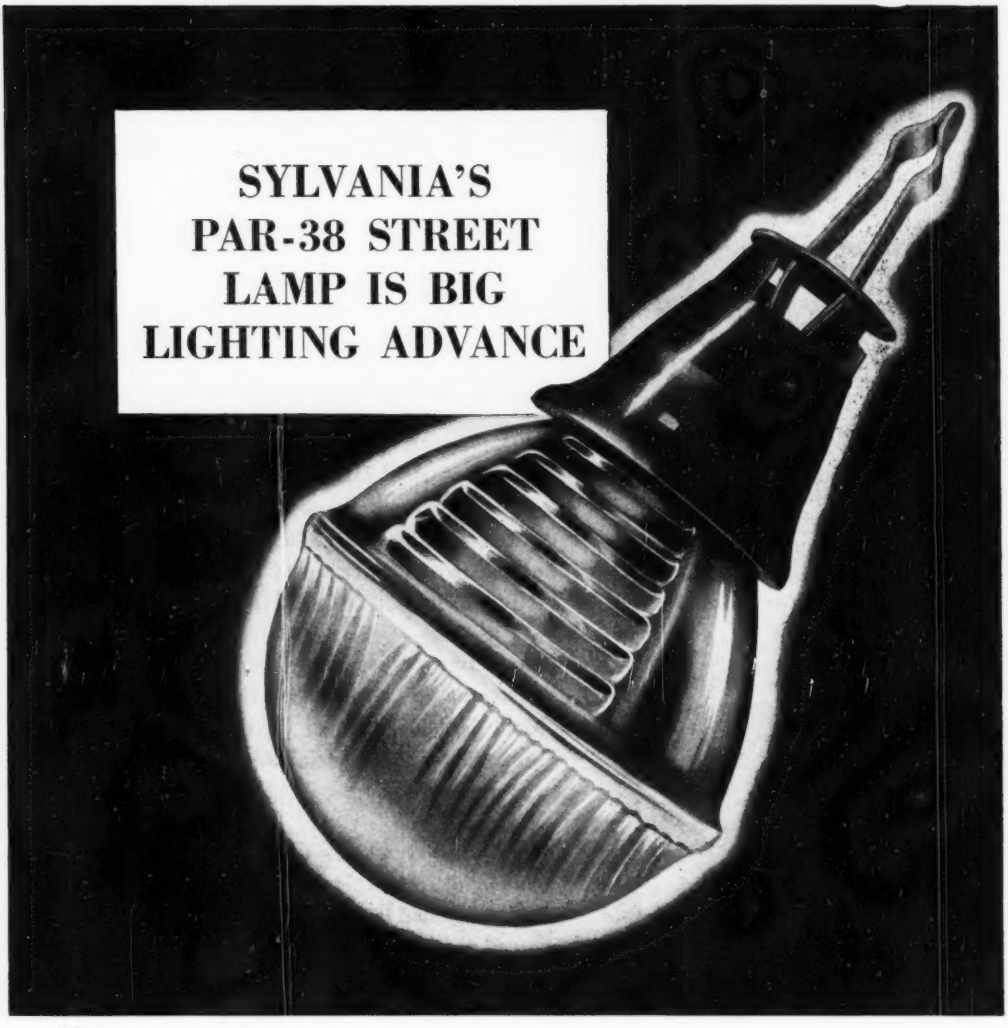
**Designs Patented*

Illuminating Engineering Company

Designers and Manufacturers of Slimline and Cold Cathode Lighting Fixtures

2347 E. NINE MILE ROAD • • • HAZEL PARK, MICHIGAN

SYLVANIA'S PAR-38 STREET LAMP IS BIG LIGHTING ADVANCE



THIS newest member of the Sylvania hard glass reflector lamp family was developed specifically for the illumination of streets and highways in residential sections, and offers most of the advantages of the larger prismatic reflector as well as many advantages of its own.

Here's a lamp whose reflector never needs polishing . . . it's built-in . . . light output is maintained at high levels throughout the life of the lamp. In addition, since the new PAR-38 is for use in residential areas, the cut-off of light is lowered to 55° on the house side and 65° on the street side, giving *more light where needed* and avoiding annoying light in second story windows! Also, this lamp is less subject to breakage than ordinary types.

The same leadership and engineering skill that developed the PAR-38 Street Lamp have made possible noteworthy advances in the fields of Radio, Television, FM, and Electronics.

ALL PRODUCTS MADE BY SYLVANIA ELECTRIC CONSUME ENERGY—MORE THAN 10,400,000,000 KWH PER YEAR

SYLVANIA ELECTRIC

Division Offices: Atlanta, Boston, Buffalo, Chicago, Cleveland, Detroit, Kansas City, Los Angeles, New York, Philadelphia, San Francisco, Seattle, Washington

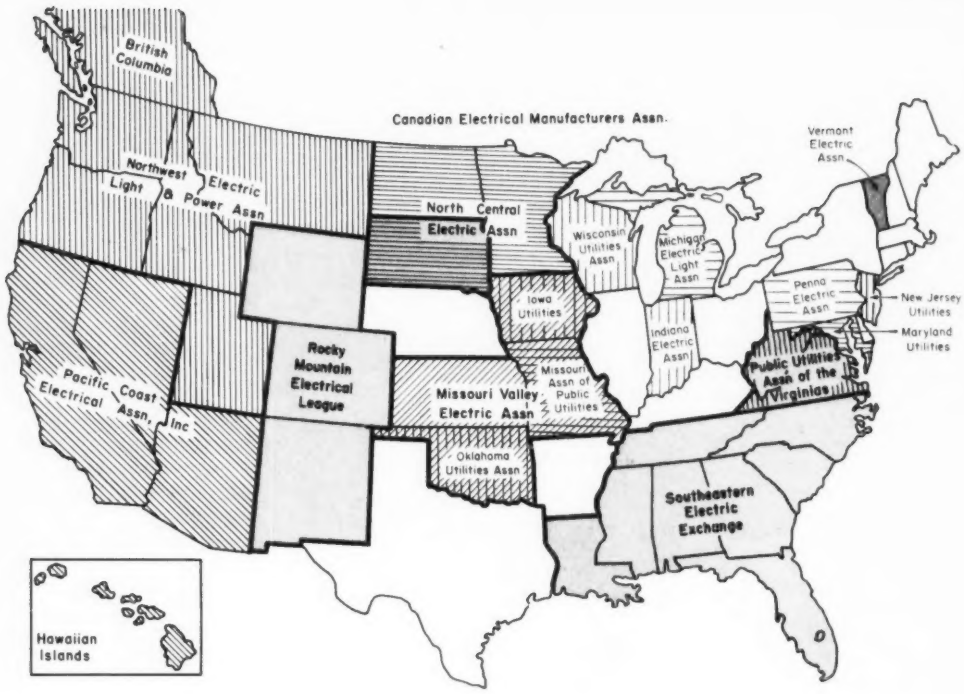
INDUSTRY ORGANIZATIONS

Many strong and able organizations are an integral part of the Electrical Industry. Functionally, they serve all of its basic branches such as Management, Engineering, Operation, Selling, and Standards.

Most of the larger organizations are national. Many are regional, and others are only state wide. Their functions and area coverage are discussed briefly in the following pages.

Space did not permit a description of the important services rendered by many industry organizations including those for fluorescent lamps, washing machines, ironers, vacuum cleaners, radios, and other electrical products. Others similarly excluded are the advertising, and public relations institutions identified by such groups as National Association of Electric Companies, National Advertising Group, and Reddy Kilowatt Service.

PUSH OUT
AND FOLD



NATIONAL ORGANIZATIONS

National Electrical Manufacturers Association
Edison Electric Institute
Association of Edison Illuminating Companies
National Electrical Wholesalers Association
American Public Power Association
International Association of Electrical Leagues
National Rural Electric Cooperative Association

REGIONAL ORGANIZATIONS

Canadian Electrical Manufacturers Association
Missouri Valley Electric Association
North Central Electric Association
Northwest Electric Light & Power Association
Pacific Coast Electrical Association, Inc.
Public Utilities Association of the Virginias
Rocky Mountain Electrical League
Southeastern Electric Exchange

STATE ORGANIZATIONS

Indiana Electric Association
Iowa Utilities Association
Maryland Utilities Association
Michigan Electric Light Association
Missouri Association of Public Utilities
New Jersey Utilities Association
Oklahoma Utilities Association
Pennsylvania Electric Association
Vermont Electrical Association
Wisconsin Utilities Association

National Electrical Manufacturers Association

B. W. Clark
President
National Electrical Manufacturers Association

FOR ITS MEMBERSHIP, comprised of the major producers of electrical goods in this country, the National Electrical Manufacturers Association performs a wide diversity of services—business development, standardization, legislative etc, as shown by the block chart. To perform these services, NEMA co-operates extensively with interests outside its membership as is indicated by note No. 2 on the chart in reference to membership in product group committees. Except as the Board of Governors may determine, membership in NEMA is limited to domestic makers of electrical goods. At present there is only one foreign member.

NEMA and its antecedents go back 44 years; the Association itself is 23 years old. In 1905 a group of 12 manufacturers of wire, wiring devices and glass insulators formed the first trade association in the industry, called it Electrical Manufacturers Alliance. As The Electrical Manufacturers Club, this association still exists.

The Ancestry of NEMA

In 1908 the American Association of Electric Motor Manufacturers was formed, became the Electric Power Club in 1910, enlarging its scope to include generators as well as motors. A further enlargement came in 1913 with admission of makers of other electrical apparatus. The Associated Manufacturers of Electrical Supplies was organized in 1915, its membership comprised of makers of electrical goods other than apparatus. Then in 1916 the Electrical Manufacturers Council was formed to co-ordinate the operations of the Manufacturers Club, the Power Club, and the Associated Manufacturers. Ten years later the two latter organizations were merged to form NEMA; the Council was dissolved; and the Manufacturers Club, transferring to NEMA its trade association functions, continued as a purely social organization.

The present functions of NEMA cover legislation affecting electrical manufacturing, developing standards for products, business development, statistics, and industrial relations.

When NEMA was formed in 1926, it set up a committee on promotion of code statutes and ordinances which assisted the regulatory legislation work of the Society of Electrical Development and kept NEMA members informed of SED activity in that line. With the dissolution of SED in 1931 NEMA assumed responsibility for the work.

At present NEMA's regulatory legislation activity revolves around the philosophy that a law should provide for safety in electrical products and their installation. A law should not erect any barriers which would prevent the sale of safe products or the use of any safe methods of installing them. In order that the progress of the industry shall not be hampered, suitable provisions should be made in law for special installations using new products or novel methods.

To this end, the principal activities carried on by the regulatory legislation department have to do with inspection and sales control legislation. Other work covers plumbing legislation which affects electrical products, safety of refrigeration, and radio interference. There is sufficient flexibility to cover miscellaneous legislation affecting specific electrical products.

Development of standards for electrical products antedates the formation of NEMA. A great many standards had been published by its predecessor associations and were incorporated into NEMA statements.

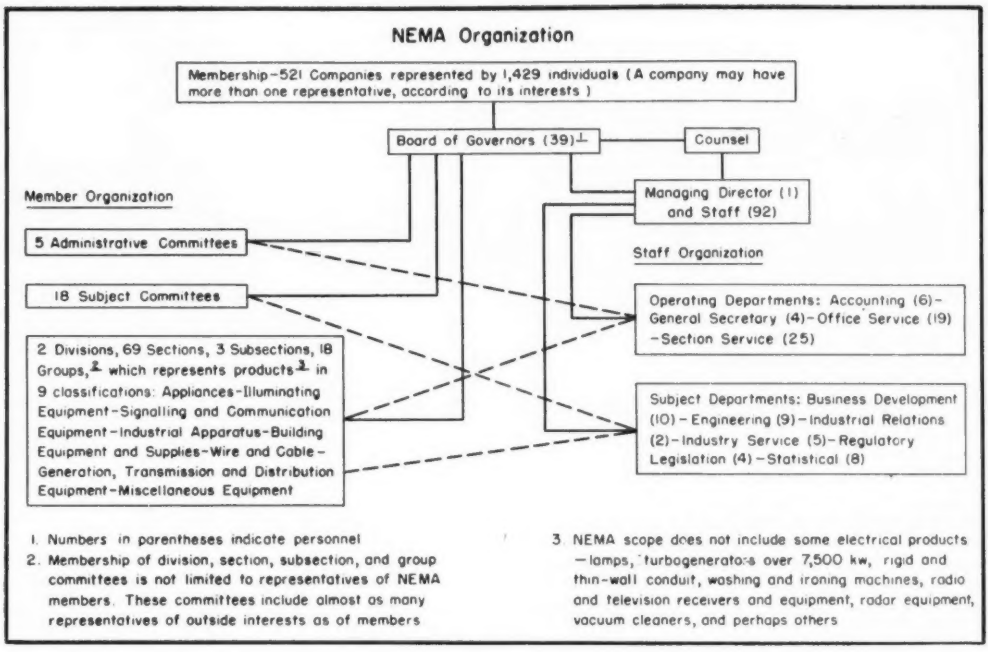
NEMA standards are adopted in the public interest and are designed to eliminate misunderstandings between manufacturer and purchaser and to assist the buyer in selecting and obtaining the proper product for a particular need. Existence of a NEMA standard does not in any respect preclude the manufacture or sale of products not conforming to the standard.

Business Development Programs

Prior to 1935, some of the subdivisions of NEMA carried on individual business development programs on a relatively modest basis. That year saw the first Association-wide coordinated effort in this line, the National Adequate Wiring Program.

This most important activity continues. While a great deal of the work must be done at the local level, principally by power companies and electric leagues, the activity must be coordinated and information concerning the program, its plans, and the manner in which it is carried out in the various localities, must

Prepared by GEO. B. CUMMING, Gen. Sec'y.


NEMA Organization
Membership–521 Companies represented by 1,429 individuals (A company may have more than one representative, according to its interests)
Board of Governors (39)[1]
Counsel
Managing Director (1) and Staff (92)
Member Organization
5 Administrative Committees
18 Subject Committees
2 Divisions, 69 Sections, 3 Subsections, 18 Groups,[2] which represents products[3] in 9 classifications: Appliances–Illuminating Equipment–Signalling and Communication Equipment–Industrial Apparatus–Building Equipment and Supplies–Wire and Cable–Generation, Transmission and Distribution Equipment–Miscellaneous Equipment
Staff Organization
Operating Departments: Accounting (6)–General Secretary (4)–Office Service (19)–Section Service (25)
Subject Departments: Business Development (10)–Engineering (9)–Industrial Relations (2)–Industry Service (5)–Regulatory Legislation (4)–Statistical (8)
1. Numbers in parentheses indicate personnel
2. Membership of division, section, subsection, and group committees is not limited to representatives of NEMA members. These committees include almost as many representatives of outside interests as of members
3. NEMA scope does not include some electrical products—lamps, turbogenerators over 7,500 kw, rigid and thin-wall conduit, washing and ironing machines, radio and television receivers and equipment, radar equipment, vacuum cleaners, and perhaps others

be disseminated among all parties of interest.

A significant number of subdivisions are carrying on business development programs individually, according to the desires of the members and their ability to support the programs financially, and to the supervision of NEMA counsel and the managing director to assure the programs will be in conformity with the law and with the policies laid down by the board of governors. These programs may include such activities as trade shows, distribution of sound films, specialized types of advertising, and cooperation with other bodies having interest in the development.

When NEMA was formed, the Electrical Manufacturers Council was carrying on six statistical activities which have been continued. These cover motors, fans, welding equipment, power switching equipment, porcelain and vulcanized fibre. The policies and procedures under which the statistical work is done are such that the highly confidential nature of individual company figures is absolutely safeguarded.

Great care is taken to see that the laws of the country, and particularly the anti-trust laws, are complied with. All of the minutes of the various subdivisions and committes are reviewed by NEMA counsel and, until they are approved by counsel, no action responsive to them may be undertaken.

Each of the subdivisions is served by a recording secretary who prepares the agenda and writes the minutes in such a manner that they will accurately describe everything of moment which transpired at a meeting. Additionally, the recording secretary follows through on all of the approved actions taken at meetings of the subdivision he serves. He assists in whatever business development work may be carried on by the subdivision and acts as liaison between it and the various departments at NEMA headquarters.

In the field of employer-employee relations, a great deal of information has been accumulated at NEMA headquarters which is available to the members. This includes data on current employer-employee policies and practices, collective bargaining agreements of various member companies, which agreements are available to the members, and regulations issued by Federal agencies.

Conferences on industrial relations subjects are arranged from time to time, as need arises, and the Association co-operates with the U. S. Chamber of Commerce, National Association of Manufacturers, and other similar bodies.

Many other activities are carried on in degrees to meet the needs of the members. Some of these are tariff, trade agreements, imports, exports, shows and exhibits information, sales financing, and manufacturers excise tax.

The Association's program comprises 63 subjects. The program for each ensuing year is reviewed very carefully by the program and budget committee, by the board of governors, and is finally approved at the annual meeting. Each item in the program outlines the problem which confronts the membership, the manner in which the project will be carried on, the manner in which the cost will be allocated among the various subdivisions, and the individual cost data for the project.

Edison Electric Institute

Ernest R. Acker
President
Edison Electric Institute

IF MILLIONS of Americans have come by now to take their unsurpassed electric service for granted, the blame—or credit—can only rest on the thousands of Americans who have given and are devoting the greater part of their lives to providing and improving that service.

Representing electric company organizations throughout the land, hundreds of these already hardworking individuals, sharing their experiences and ideas, have made the Edison Electric Institute what it is—a national cooperating group, dedicated to the ideal of progressively better electric service. The companies making up the Institute comprise the greater part of the electric industry. Acting in concert through their committee representatives, they formulate policies, organize working groups, and undertake various programs to fulfill the Institute's mission.

More than 950 electric company executives are serving on the 41 committees of the Institute. These committees, grouped under the major headings of Accounting, Commercial, Engineering and General, are frequently subdivided within themselves, as groups of the parent committee undertake special assignments, or prepare special reports.

Values of Committee Work

Over the years, committee members have, by their painstaking and unpublicized attention to the details of electric utility operation, helped make an industry pattern of progress which is unexcelled. In sharing experiences, knowledge, and achievement, the members of the committees offer an outstanding example of group responsibility to the public their companies serve. Another consideration, apart from more direct benefits to the industry and the nation, was pointed out by former EEI President Kellogg ten years ago, when he said that the services of these men "also give an opportunity to discover and develop the coming young men who will lead in carrying on our service in the future."

Based solidly upon its foundation of strong unobtrusive committee work, the Institute has been able to build an important informational structure which seeks to keep member companies posted on pertinent happenings and developments affecting them.

The two main collecting points of informational raw material in the Institute are its extensive service library and its statistical department. Basic industrial and economic reports from hundreds of sources, periodicals, newspapers, clippings, and other publications received in the library make it possible for the Institute to issue to chief executives of member companies frequent information letters, containing, among other information material, reproductions of important items relating to the electric industry. The Institute also periodically lists as available to member company executives significant publications, transcripts of speeches, and reports.

Many Informational Services

In the statistical department, data from companies all over the country are collected and tabulated and the results used in the weekly and monthly capacity and output reports. The annual Statistical Bulletin provides comprehensive coverage of the important phases of industry operation during the preceding year.

EEI statistics are viewed as authoritative by individuals and organizations in the business and professional world outside of the electric industry.

As the story of the industry unfolds from day to day with developments in different fields affecting not only the companies but the public as well, the Institute draws on its wide variety of resources and issues occasional factual releases to newspapers and wire services. Pamphlets and special informational pieces are also prepared from time to time as definite occasions make them desirable.

In meetings and at conventions, EEI committees have brought all their efforts to bear on the present expansion program of the industry. To make sure that the new capacity would pay its way, EEI committees have been engaged in ironing out the final details in new intensive sales campaigns. Thus, as the abnormally high rate of increase of demand slackens, with the sating of immediate postwar needs, EEI launches its "All-Electric Kitchen" program to help keep the industry growing at a healthy pace.

Formed on January 12, 1933, the Edison Electric Institute began its career during a period of economic chaos. EEI's first president, George B. Cortelyou,

speaking at the new group's initial convention held in Chicago in June of 1933, called the event "a beginning and a continuation" and pointed out that EEI's predecessor, the National Electric Light Association, had held its first annual meeting nearly half a century earlier in the same city. Caught up in the whirl of changing conditions, NELA had been dissolved in February, 1933, after having contributed greatly to the electrical art since 1885.

Eschewing the far-flung complexity of NELA, the organizers of EEI set out "to build simply." Their objectives, as detailed in the Institute's Constitution, were three: "The advancement in the public service of the art of producing, transmitting and distributing electricity and the promotion of scientific research in such field; the ascertainment and making available to the members and the public of factual information, data, and statistics relating to the electric industry; and to aid its operating company members to generate and sell electric energy at the lowest possible price commensurate with safe and adequate service, giving due regard to the interests of consumer, investor, and employee."

Practicalities in Regulation

One example of the valuable service rendered by EEI committees during the pre-war period came about as a result of demands by regulatory authorities for the maintenance of certain additional records by the electric companies. It was largely through the efforts of accounting committee members that the commissioners came to appreciate the vast and costly amount of unnecessary detail that would be involved, and the regulatory requirements were ultimately reduced to more practical specifications.

The commercial division, having begun its career at the bottom of the depression with the slogan "Sell Our Way Out," has compiled an impressive record of successful campaigns to achieve this aim. The oldest, as well as one of the most effective, cooperative programs in the electric industry, the "Better Light-Better Sight Bureau", is now in its fifteenth year. In the extremely important field of kitchen modernization, one of the largest programs ever sponsored by the industry was launched in 1935, shortly developing into "The Modern Kitchen Bureau" which conducted extensive national advertising and promotional campaigns in cooperation with manufacturers' groups.

Becoming a valuable forum for the discussion of operating and maintenance problems, the engineering division grew from its modest beginnings until it contained as it does now, standing committees covering electrical equipment, hydraulic power, meters and service, prime movers, and transmission and distribution. In addition, special subcommittees were authorized to study specific problems.

The interchange of ideas and experiences which took place in the meetings and conferences resulted in new methods of increasing efficiency and economy. Also, while the committees themselves took no part in actual design work, their deliberations and reports led, with the aid of industry members and manufacturers, to standardized designs in equipment, the resultant economies being passed on to member companies.

Other committees activated during EEI's pre-war years included groups concerned with accident prevention; codes and standards; insurance; membership; prize awards; purchasing, stores and transportation; rate research; and statistics.

A striking example of the value of committee work, chosen principally because it may be most easily measured in dollars and cents, is offered in the achievement of the insurance committee. The cost of insurance coverage for the industry was so reduced as a result of the committee's efforts that the annual saving to the industry more than equalled the annual dues of all Institute members.

As events in Europe became increasingly disquieting, the United States began to take stock of its ability to defend itself. In his address at the 1939 EEI convention, Institute President C. W. Kellogg assured the country that there would be ample electricity, should war come, to undertake all the vital necessary tasks and to supply civilian needs as well.

Backed by a long tradition of working together and handling problems as a group, the electric companies and their Institute were able to meet every contingency of World War II. In spite of material and manpower shortages, the industry wrote a brilliant chapter in its already remarkable history, meeting a previously unequalled peak load in 1944 with capacity to spare, and cooperating in every possible way to conserve less plentiful necessities such as gasoline, coal, and rubber.

Among the many congratulations offered members of the industry for their wartime performances, the oft-repeated and unforgettable tribute of Admiral Monroe stands out: ". . . you delivered, each and every one of you . . . When we called for power we got power and not—thank God—alibis."

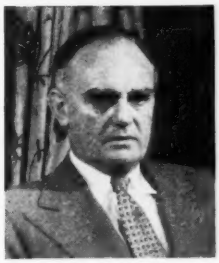
Preparing for Post-war Years

Months before the war was over, before these laurels could be delivered, the EEI was looking to the peacetime years ahead. New members joined the Institute, and the constitution was amended to provide, through an advisory committee, increased opportunity to draw on top-level experience and judgment.

The commercial division provided one of the more dramatic examples of EEI readiness for peace. Realizing that the change in economic climate would be a severe test to companies with largely inexperienced sales forces, the commercial committees had a complete sales training program ready for use in 1946. More than 200 companies engaged in the program, and it was judged a major success.

With very slight alteration, the closing sentences of an ELECTRICAL WORLD editorial of 1921 on the National Electric Light Association might apply: "The work of the Edison Electric Institute, while it is most indispensable, essential and vital to its members, is largely a labor of love in the service of the public, which benefits through more and better service at minimum cost. Animated by this spirit, the Institute has grown to its present stature."

Association of Edison Illuminating Companies



J. W. McAfee
President
Association of Edison Illuminating Companies

THIS ASSOCIATION is an unincorporated non-profit society which has as its present active members fifty-two operating electric utility companies.

It has been in continuous existence since it was organized in Harrisburg, Pennsylvania, on April 15, 1885, by a group of electric light companies which were licensees under Thomas A. Edison's patents controlled by the Edison Electric Light Co. The primary requirement of a licensee status for membership in the Association was dropped from the By-Laws some years ago. The present membership is composed substantially of the corporate successors of companies that were originally licensee companies.

The By-Laws provide:

> "The object of the Association is the advancement of electric service to the public for light, heat and power."

The small and struggling companies which were endeavoring to supply energy through three-wire multiple circuits as contrasted with the series lighting circuits found themselves surrounded by difficulties and dependent on the Edison Electric Light Co (Edison's manufacturing interest) under whose patents they were licensed to operate. They, therefore, formed an association for mutual helpfulness in overcoming operating and technical problems.

When the Edison Electric Light Co was organized, it undertook among other things to render an advisory service to its licensees, and to them alone, as there was competition with other systems. Owing to the pioneer nature of the industry and the scarcity of knowledge, this service quickly became a most imposing task. To simplify the problem and still confine the service to Edison licensees alone, the AEIC was formed, giving all member companies periodic opportunity to contact the parent or licensor company and get together and exchange ideas, problems, practices and experiences. This 'information exchange' left the parent Edison company opportunity to concentrate on those advisory services which could not be handled by exchange of experience within the AEIC.

The intimate and informal discussions by senior executives of the operating companies resulted in technical developments and improvements in manufacture being stimulated and accelerated by the critical and frank presentation of the operating experiences of the utility companies. Similarly the characteristics of utilization equipment and the difficulties experienced with it on the companies' lines were continually discussed with the manufacturers and steady efforts were made toward the improvement of their performance—a notable example of this being power factor performance of small motors.

It has been the nature of the Association that its meetings were essentially intimate conference meetings rather than for definitive "action".

At the time of organization there were four member companies. By 1887 this had increased to 45 out of the 90 Edison licensee companies. In 1942 there were 61 member companies representing almost half of the country's total electric utility output. The membership at the present time, due largely to mergers and consolidations, is 52 companies.

The AEIC at its annual meetings represents an organization which provides a forum where operating matters of all kinds can be frankly discussed and analyzed to provide guidance.

The Association has had a long record of accomplishment through its committees and outstanding individuals connected with the various member companies. It became a potent force for progress in the utility business. Many company-initiated research projects were taken over by Association committees and extended to cover industry-wide variations in the problem. Outstanding accomplishments included:

Improvement of incandescent lamp performance.
Formation of a Meter Code, stressing value of accuracy.
Standardization where it does not hamper progress.
Early standardization of accounting.
Early advocacy of low rates, uniformity, and equitable form.
Development of cables, switches and switchgear, turbines and generators (always in cooperation with manufacturers).
Economic analyses of applications versus salesmanship.
Aid in improving the National Electric Code.
Lowering of unit costs and reduction of energy losses.
Improvement of power factor performance of small motors.
Study and development of rates for electric energy taking into account the effect of power factor.

Prepared by F. V. MAGALHAES, *Secretary*

National Electrical Wholesalers Association

E. B. Ingraham
President
National Electrical
Wholesalers Association

THE National Electrical Wholesalers Association, which now includes more than nine hundred leading electrical wholesalers and appliance distributors on its membership roster, is completing its forty-first year of continuous service. Member companies of NEWA hold membership in the Apparatus and Supply Division or the Appliance Division or both.

Objectives of the Association are to promote the welfare of its members and to distribute among them the fullest information obtainable in regard to all matters affecting the electrical apparatus and supply and appliance wholesale business; to aid in bringing about more friendly relations between the electrical apparatus and supply, appliance wholesalers and others engaged in the electrical business; to assist in standardizing and marketing high-grade electrical merchandise and in reducing fire hazards; to improve the quality of electrical goods marketed by American manufacturers and the service rendered by the various branches of the industry.

When organized in 1908 at a meeting at Niagara Falls, Canada, with some seventy-five charter members, this group was known as the Electrical Supply Jobbers Association. Twenty years later at a meeting at Hot Springs, Virginia, in 1928, the members voted to change the name to National Electrical Wholesalers Association. Recently the membership of NEWA was divided into nine territorial zones. Elections of members of the Board of Governors and the Executive Committee provide for equal representation from the zones and from the two divisions of the Association.

The direction of the Association's program of activities and services is vested in the Board of Governors which meets twice a year, in the spring and fall. A smaller Executive Committee of seven members, including the president and the directors of the two divisions, has the responsibility of directing the Association's work and over-all management of its various activities between meetings of the Board of Governors of the association.

There are 42 committees designated as General committees and Commodity or Functional committees. Those in the last two classifications are committees within the Appliance Division or the Apparatus and Supply Division. Printed committee reports are issued to member companies to keep them informed.

Indicative of NEWA committee work are some of the special committee activities that are an integral part of the Association's "Program for Progress." These include:

A basic sales training program prepared in cooperation with the Edison Electric Institute.

A scientific personnel selection program designed to assist both member companies and their dealers in solving the problem of recruiting and selecting personnel, improving its efficiency and accelerating advancement.

A suggested *Standard Page for Wholesaler Salesman's Catalog*—a four-page printed folder presenting complete details of dimensional and typographical layout to provide uniformity and "practical workability" in the catalog pages prepared by manufacturers and used by salesmen of electrical wholesalers to compile their own working catalogs. This activity was supplemented by a series of four humorous cartoon pages to serve as reminders to those suppliers whose catalog pages were being sent to NEWA members in such form that they could not be used.

NEWA Warehousing Committee Reports—*Manual of Experience*. This thirty-two-page illustrated Manual, prepared with the cooperation of the editorial staff of *Electrical Wholesaling*, has been extensively used throughout the industry and highly commended. An amended Manual is now in preparation.

Television Service and Installation. This Manual of Experience, which was published last year for the benefit of members interested in the problems of television sales, service, and installation, is now being revised and will be re-issued as a similar type of publication directed to the specific problems of service and installation encountered by dealers.

About a year ago, as a result of a Committee project, the Association began the publication of a series of *Sales Boosters* designed to help the salesmen of its member companies help their dealers and other customers.

In addition, the Association periodically issues a *Newsletter*. At the present time the Association has in a preparatory stage an extensive program covering industrial relations, with which will be combined a number of public relations features.

Prepared by ALBERT PFALTZ, *Public Relations Manager*

Other National Groups

American Public Power Association

This Association is a service organization, created by existing publicly-owned electric operating systems and intended to promote more efficient management of such systems. It is financed by membership fees and service contracts. It is non-political and non-partisan and is prohibited from engaging in propaganda. President is Thomas H. Allen.

Advisory and management services are provided members by a full time staff, supplemented by such outside consulting assistance as may be necessary. Studies and research projects are undertaken from time to time as authorized by the Board of Directors. A weekly News Bulletin is sent to members and a monthly magazine *Public Power* covers the entire publicly owned field with a circulation over 10,000 copies. An annual convention is held in different parts of the country.

Committees are assigned various tasks and projects to undertake and report on at regular meetings. Committees are: General Operation, Public Relations, Legal, Accounting and Finance, Legislative, Membership.

Affiliated with the National Association are the following state and regional groups: California Municipal Utilities Assn, Central Service Assn, Indiana Municipal Electric Assn, Iowa Assn of Municipal Utilities, Kansas Assn of Municipal Utilities, Municipal Lighting Assn of Mass., Michigan Municipal Utilities Assn, Missouri Association of Municipal Utilities, New York Municipal Electric Utilities Assn, Northwest Public Power Assn, Tennessee Valley Public Power Assn, and Wisconsin Municipal Utilities Assn.

National Rural Electric Cooperative Association

This Association is the trade organization of rural electric cooperatives, public power districts, and public utility districts throughout the United States and its territories. Incorporated in the District of Columbia in 1942, NRECA is a non-partisan, non-profit organization which includes 85% of the nation's rural electric systems as active members, representing approximately 2 million connected consumers. President is Clark T. McWhorter.

Information and publication, legislative, radio intracommunication, and research programs are among Association activities. Last year NRECA added a comprehensive autonomous retirement and security program on a nation-wide scale for employees of member systems to long-existing liability and group life insurance activities. The Association's monthly publication is circulated to all managers, officers, directors, attorneys, and education and public relations personnel of all rural electric systems—member and non member alike—in addition to members of Congress and officials in Government agencies. Legislative activities include appearance of executives, officials and committees before various committees of the Congress as well as compilation of surveys and preparation of other information for the Congress.

International Association of Electrical Leagues

The International Association of Electrical Leagues is an association of associations, its membership being comprised of leading electrical leagues which operate in most of the important centers throughout the country. The international flavor is provided by the several Canadian member groups. President is J. C. Chamberlain.

The IAEL was launched in 1936, to fill the vacancy caused by the disbanding, in the early 1930's, of the former Electrical League Council.

In addition to providing electrical leagues with a medium through which they can express themselves on electrical affairs of national interest, the IAEL promotes the interchange of thought and experience among its member organizations; promotes acquaintanceship and fellowship of men engaged in expanding the electrical market through cooperative means; acts as a medium through which nationally developed, cooperative programs can be put to work; serves as a clearing house in correlating and disseminating information of common interest; and facilitates cooperation among all branches of the electrical industry, locally. It also organizes and conducts an annual conference, which offers an opportunity for the presentation of information about new market expansion programs developed in the electrical industry, and for an interchange of experience on programs already in operation.

The Board of Governors consists of nine men, who are elected at the annual conferences and who represent the constituent members of the five territorial divisions into which the United States and Canada are divided. The members of the Board of Governors must be full-time paid operating managers.

For more information on Electrical Leagues see Regional Organizations.

Regional Organizations

Southeastern Electric Exchange

At the dissolution of the National Electric Light Association, a group of prominent utility executives in the Southeast met in Atlanta on June 6, 1933 and organized the Southeastern Electric Exchange, electing Jack W. Hancock, Appalachian Electric Power Co, Roanoke, Va., as its first president. Present president is S. C. McMeekin, president, South Carolina Electric & Gas Co.

The primary object of the organization is to advance to the fullest the development of the electric industry in all its branches including the exchange of factual information and data relative to the electric industry. Starting with 22 chartered members, now there are 31 members representing the private companies operating in the nine Southeastern states, with the Duke Power Co being the only exception.

The Accounting, Engineering and Operation, and Sales Sections were established in 1934, and others have been added since that time as conditions of the industry in the region demanded and today there are 15 committees and sections—the members of each have been liberal with their time and skill in making the work they have undertaken successful and fruitful.

Missouri Valley Electric Association

This association operates chiefly in the four states: Iowa, Missouri, Kansas and Oklahoma. Members are electric utility companies. President is D. C. McKee, Empire District Electric Co.

Acitivities are built around the encouragement of an interchange of ideas, methods and practices of member companies in the several technical fields vital to the operation of the electric light and power industry. The chief vehicle is a periodic one or two-day all-business round-table type of meeting where free and open discussion of problems is carried on.

Seven groups do the work: (1) Accounting, including Business Machines, Customers Records, Fixed Capital, General Records, Purchasing & Stores, and Statistical committees; (2) Engineering, including Accident Prevention, Electrical Apparatus, Foreign Systems, Internal Combustion, Meter, Overhead Systems, Power Systems, Prime Movers and Underground committees. The other groups, (3) Sales & Rural, (4) Power Sales, (5) Personnel Administration, (6) Rate Practice and (7) Special group on public relations are not subdivided.

The association also sponsors the Utility Communications Association. It operates in its area and certain adjoining states and deals with the problems of emergency short-wave radio use by utility organizations.

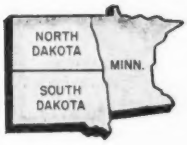
Northwest Electric Light & Power Association

This association was organized in Seattle, Wash., in 1908 and has been in continuous operation since.

It was organized primarily as an electric utility association but has since broadened its scope of activities to include membership from electrical manufacturers, jobbers, wholesalers and distributors, and a limited number of electrical contractors and retail dealers. Territory covers: Washington, Oregon, Idaho, Montana, Utah and the province of British Columbia, Canada. President is W. L. Thrailkill, Washington Water Power Co.

Its scope of activity is primarily educational within the industry, though on occasions it has sponsored promotional activities directed to the public. It carries on its activities through four sections and three independent committees. Sections are: Accounting and Business Practice, Business Development, Engineering and Operation, and Personnel, some of which breakdown into bureaus and sub-committees. The three independent committees, functioning outside of the sections and reporting directly to the president and executive committee, are: Advertising and Publicity, Purchasing, and Rate Research.

North Central Electric Association



This association was established in 1920, and was a combination of the electrical associations of Minnesota, North and South Dakota. T. D. Crocker, late president of the Northern States Power Co was its first president. Present president is E. H. Finkelnburg, Mississippi Valley Public Service Co.

Activities include: Operating Executive Advisory Committees: Production Engineering, Transmission–Distribution Engineering, and Safety. Sales Executives Advisory Committee: Merchandising; Power & Subsidized Competition; and Rural Development. Other committees: Rate Research: Accounting; Land & Tax; Industrial Relations; Missouri Valley Development; Public Relations; and South Dakota Electrical.

Pacific Coast Electrical Association, Inc

This association, organized in 1917, functions in California, Arizona, Nevada, and the Hawaiian Islands. The membership consists of over 2,800 individual personal members, and over 200 companies from all branches of the electrical industry—utilities, manufacturers, manufacturers agents, wholesalers, contractors, dealers, inspectors, engineering firms, and electrical publications. M. G. Sues is president.

The association serves a two-fold purpose: (1) Within the industry, it fills the need for a forum for the exchange of ideas and experience, and the discussion of mutual problems, while (2) externally, it serves as an agency for the promotion of adequate wiring, uniformity of local codes and ordinances, and a more efficient and comprehensive use of the many services and facilities which the electrical industry offers to its customers.

In addition to the committees which carry on the promotional efforts, it is customary to hold two general meeting a year—a Fall Conference, and the Annual Convention.

The research and promotional committees, functioning at the present time, are: Highway Lighting, Agricultural Electrification, Liquefied Petroleum Gas, Safety Rules, Metering, Communications, Code and Ordinance, Publicity, Advertising, Home Lighting, Modern Kitchen, Home Laundry, Home Economics, Television, and Adequate Wiring.

Public Utilities Association of The Virginias

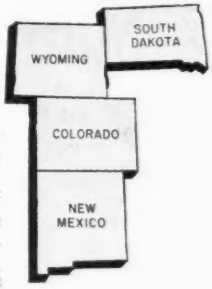
The Public Utilities Association of West Virginia was formed June 15, 1915. During World War I it became dormant and in 1920, it was reorganized. In 1940, the Association was broadened to include companies in the State of Virginia and the name changed to Public Utilities Association of the Virginias. As now constituted, membership consists of electric power, water service, city bus lines, telephone and artificial gas companies. President is R. F. Randolph, Charleston Transit Co.

The association publishes the *Public Utilities Association Reporter* twice each month, briefly reviewing the orders of the Public Service Commission of West Virginia.

The Electric Power Section has these standing committees: Load Building, Industrial Relations, Industrial Power, Area Development, Rural and Accounting.

The annual meeting of the association is held in the fall of each year. Committee meetings are held at the call of the chairmen of the various committees.

Rocky Mountain Electrical League



The Rocky Mountain Electrical League includes the states of Wyoming, Colorado, the northern half of New Mexico and the Black Hills area of southwestern South Dakota. Predecessor organizations of the league started in August, 1903. H. T. Rankin is president.

Membership includes 27 electric utilities, 54 manufacturers and distributors, and many electric contractors and dealers, associated more directly with local leagues.

Most activities are administered by committees, including: Adequate Wiring, Engineering, Accounting, Sales and Promotion, Go All-Electric Promotion, Rural Development, Mobile Radio Communication. Also five major divisions have their own chairmen and committees. The league is the authorized certifying agency for adequately wired homes in the area. The Go All-Electric Program, based on NEMA's plan, is in its second year.

The Radio Communication Committee, or officially the Rocky Mountain Utility Radio Association, is the agency authorized by the Federal Communications Commission. It allocates frequencies for all groups in this area operating under Committee 4 of Panel 13,

Radio Technical Planning Board, solely responsible for the formulation of national Power Utility Radio Policies.

Other Electrical Leagues

The North Central Electrical Industries represents another large area electrical league similar to the Pacific Coast Electrical Association and the Rocky Mountain Electrical League. Participation in the North Central association includes not only private electric utilities, manufacturers, wholesalers, and dealers but also municipal utilities and electric cooperatives. It provides an example of outstanding cooperation among diversified industry groups.

There are over fifty league organizations in the country. The most active among the others are Electric Institute of Washington; Electrical League of Cleveland; Electrical Association of Philadelphia; The Electric Association, Chicago; Electric Institute of Boston; Electric League of Chattanooga; Electrical and Gas Association, N. Y.; Electrical Association of Detroit; Electrical League of Indianapolis; The Electrical League of Milwaukee; St. Louis Electrical Board of Trade; and Electrical League of Western Pennsylvania. Basic activities of all fifty leagues are the same.

Canadian Electrical Manufacturers Association

This association is composed of manufacturers of electrical products throughout Canada. It is estimated that the 118 companies which comprise its present membership represent about 90% of the dollar output of the electrical manufacturing industry of Canada.

The Canadian Electrical Manufacturers Association was organized in 1944 and incorporated under Dominion law in 1945. President is G. W. Lawrence, president of Sangamo Co Ltd.

Activities include close cooperation with electric utilities. In fact, CEMA's recent publications "Adequate Wiring To-day for Electrical Living To-morrow" and "Electricity on the Farm" were produced in cooperation with many Canadian utilities.

Objects are to promote the interest of manufacturers of electrical products and to stimulate the interest of the public in the manufacturing, engineering, safety, transportation and other problems of the electrical industry.

State Organizations

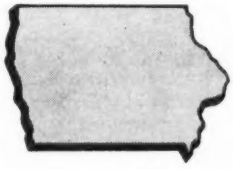
Indiana Electric Association

This association, with predecessor associations, has been in continuous operation for approximately 50 years. President is G. J. Oglebay, Public Service Co of Indiana, Inc.

Membership in the association is made up of all privately owned electric utility operating companies in the state with the exception of a few extremely small ones. Most of the Association activities are carried on by standing committees. These include: Accident Prevention, Accounting, Personnel & Industrial Relations, Power Production, Rates Statistics, Transmission & Distribution, Transportation, Sales Promotion, Highway Lighting, Industrial-Commercial.

The Association is interested in farm electrification research and has made annual contributions to finance research work at Purdue University for over 25 years. Several years ago member companies contributed an amount of $43,000 for the purchase of a farm to be used in demonstrating the proper and efficient use of electric power on the farm and in the farm home. Since 1946 awards have annually been made available for 4-H Club members participating in the Better Farm and Home Methods Electric Program. Each year the Association sponsors a Young Men's Utility Conference.

Iowa Utilities Association



This association has a membership of all the privately owned electric and gas companies in Iowa, including two separately owned transportation lines. President is Chas. E. Strickland, People's Gas and Electric Co.

The association disseminates news bulletins of general interest to the company members, and also keeps a record of all rates. Three meetings of the Executives of the Association are held annually. Activities are confined in general to these committees: Research, Farm Study, Public Relations and Advertising.

Maryland Utilities Association

This association was formed in 1922 at Baltimore by the publicly regulated Maryland utilities. Membership includes major electric, gas, telephone and transportation companies, and their allied manufacturers and dealers. President is Adrian Hughes.

Its purpose is to develop practices and policies beneficial to its members and their customers; to promote understanding and cooperation between employees, customers and stockholders; and to secure uniform and just regulation, equitable to both the utilities and the public. Conferences are held in April and September.

Committees are: Taxation; Communications; Rural Electrification; Public Relations, and Arrangements.

Michigan Electric Light Association

This association has twelve member companies all of which operate wholly or partly in Michigan. President is S. F. Massie, Michigan Gas & Electric Co.

Five committees serving the association are: Accounting, Farm Service, Lighting Sales, Merchandise Sales and Wiring. They hold meetings from time to time in order to keep abreast of new developments and methods, and discuss mutual problems and procedures. Their members are appointed by the member companies and each committee assignment is for the term of one year.

Missouri Association of Public Utilities

This association was organized on October 21, 1907. It is a non-profit association of investor-owned electric, gas, and water utilities. President is J. W. McAfee. Objects of the association are: (1) To promote the common economic and scientific interests that are compatible with public welfare; (2) to acquaint the public with the rightful purpose and place of investor-owned electric, gas, and water service in the economic structure of the nation; (3) to foster better understanding and cooperation between its members and other dealers in merchandise, appliances, and services essential to a greater utilization of electricity, gas, and water; and (4) to promote safe standards of operation.

Standing committees are: Accident Prevention; Advertising; American Gas Association Managing Committee; A.G.A. Committee on Improving Domestic Gas Appliances; Auditing and Statistical; Labor Policy; Taxation; Power; Rural; Sales; Convention; and Uniform Classification of Accounts.

New Jersey Utilities Association

This association was organized in 1914 and for 35 years has followed its objective of promoting the interests of the Public Utility Companies of New Jersey who are its members. President is Franklyn Heydecke, Public Service Electric & Gas Co.

The affairs of the association are managed by the Executive Committee and the Board of Directors. There are no standing committees. Special committees are appointed for specific purposes as the needs arise, and are discharged as soon as their work is completed. The annual meeting is held in November and there is a spring conference each May.

Active membership is available to any individual, co-partnership, association, corporation (except a municipal corporation), or joint stock company owning, managing or operating plant or equipment for public use; such as steam railroad, street railway, traction railway, canal, express, subway, pipeline, gas, electric light, heat, power, water, oil, sewer, telephone, and telegraph. Associate membership is available to manufacturers and dealers in supplies for utility companies, also engineers and contractors engaged in construction of public utility plants.

Oklahoma Utilities Association

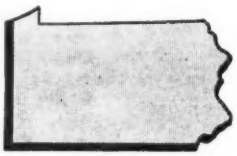
This association is composed of the electric companies and the gas companies of the State. President is Malcolm Morrisson.

The association has an Electric and a Gas Division. The Electric Division has two sections: the Eastern District and the Western District. During the year each District holds a meeting where experts discuss technical matters affecting the industry. W. R. Wolfe, Oklahoma Gas and Electric Co, is general chairman.

The Gas Division holds an annual meeting where technical matters covering the natural gas industry are discussed. D. W. Reeves, Oklahoma Natural Gas Co is general chairman. Each year the two divisions have a joint meeting of interest to both the gas and electric utility companies.

The association is also one of the sponsors of The Southwestern Gas Measurement Short Course which is held at the University of Oklahoma for three days each year.

The Pennsylvania Electric Association



This association is a voluntary trade organization of companies engaged in, and individuals affiliated with or interested in, the electric light and power industry in Pennsylvania. The object of the association is to advance the art and science of the production, distribution and utilization of electrical energy for light, heat and power. President is W. H. Doran, Metropolitan Edison Co.

The 33 operating company members cover practically the entire service area in Pennsylvania. The Executive Committee, comprised of fifteen elective members, is the committee that has supervision and control in the administration of the activities and business of the Association.

Activities are carried on by four sections:

(1) Accounting Section, has four committees to study accounting principles, methods and practices and to do research.

(2) Business Development Section, has eight committees, to analyze and encourage the development of the electric utility industry and retention of existing business; to improve relations with customers; to cooperate with other branches of the electrical industry; to help obtain maximum economy and satisfaction in the use of electric service.

(3) Engineering Section, comprised of eight committees, is to accelerate the development of the art through studies of important engineering problems and interchange of ideas; to keep abreast of the latest and best developments and operating practices in power system engineering by providing opportunity for discussion of their problems; to broaden the vision of engineers, particularly the younger men, through contact with other engineers engaged in related lines of work; to set up authoritative engineering policies in matters dealing with codes, standards and other subjects in which engineering contact is had with outside interests.

(4) General Section, comprised of five committees, is to discuss, study, and conduct research in various operating phases of the electric utility industry and particularly in matters affecting employee morale and efficiency and such specialized activities as Motor Transportation, Stores and Rights-of-Way.

The committees of the various sections have two or three meetings each year to study and report on current problems confronting the industry.

The activities of the association are culminated in an annual conference held in September of each year.

Vermont Electrical Association

This association was formed July 9, 1902, at Bellows Falls, Vermont with sixteen representatives of Vermont electric corporations present. The object of the association is to foster and develop the electrical industry in the state of Vermont. President is Myron G. Clapper, Newport Electric Div, Citizens Utility Co.

Members come from corporations, individuals and municipalities engaged in producing and supplying electricity for commercial and public use, together with electrical manufacturers and dealers representatives. Meetings are held in the spring, summer and fall. They are of a social, educational, and good fellowship nature. Membership is about 200.

Wisconsin Utilities Association

This association was organized in 1920 as a successor to separate electric, gas and transportation associations. It acts as a clearing house of information for Wisconsin companies. President is W. E. Schubert, Wisconsin-Michigan Power Co.

The association has four sections: Electric, Gas, Transportation, and Accounting. The Electric and Gas Sections are divided into technical and sales and service divisions. Each section usually holds its own convention each year. Approximately 255 members serve on the committees. Each committee is given annual assignments for study. Final conclusions are recommended to the Advisory Committee of their own sections, which makes its recommendations to the Executive Committee.

The association purchased a 144-acre farm, which is operated by the University of Wisconsin. Research work is being conducted at the Electric Research Farm to learn whether chore time on dairy farms cannot be cut in half through proper location of buildings and use of automatic electric equipment.

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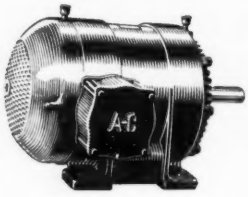

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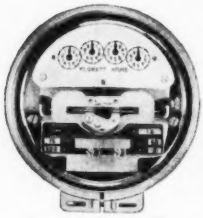

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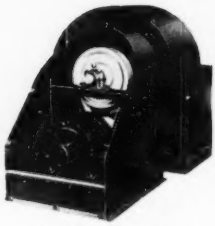
Meters



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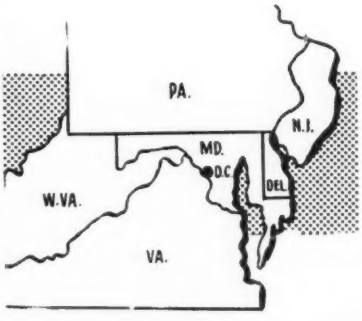

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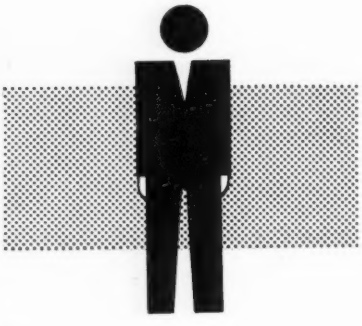

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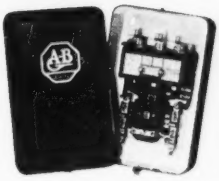

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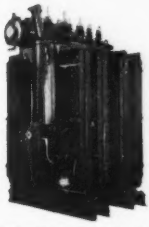

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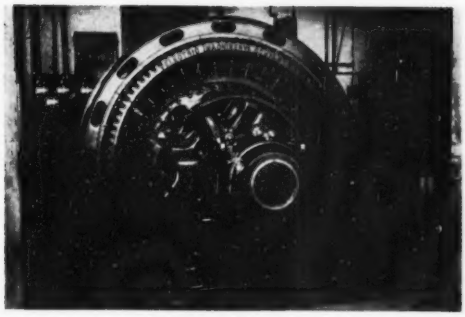

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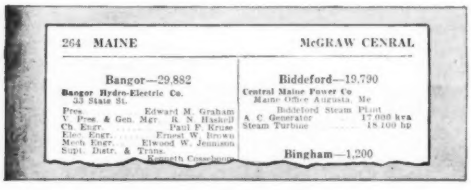
- Plant Superintendents
- General Superintendents
- Purchasing Agents
- Division or District Superintendents
- Chief Engineers
- Electrical Engineers
- Plant Engineers
- Merchandising Managers
- Division or District Managers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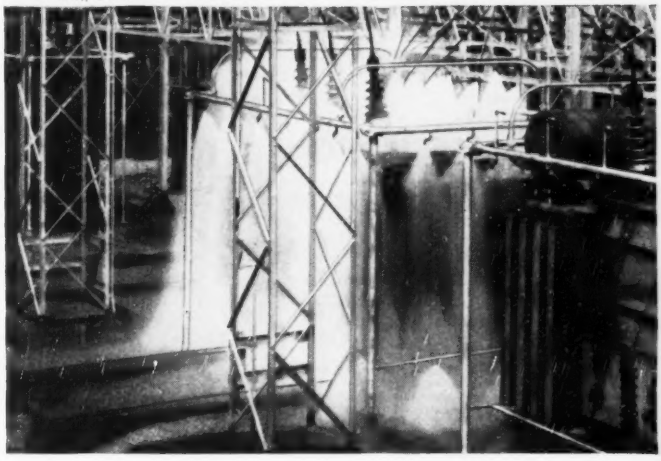

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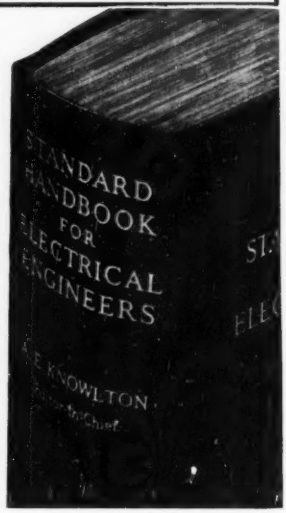

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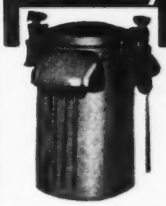

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1—1500 KW G.E. 2300v., 3 ph., 60 cy. with G.E. 225 lbs. cond. turbine, surface condenser
2—750 K.W G.E. condensing, 3600 250 lbs. Surface condenser, 3 ph. 60 cyc. 440v. dir. conn. exciters
1—300 K.W. G.E. non-condensing 175 lbs., 5/15 lbs. B.P. 3 ph., 60 cyc., 480 v. Dir. conn. exciter
1—1000 KW. G.E. 2300/4150v, 3 ph., 60 cy. with 135/150 lb. condensing turbine

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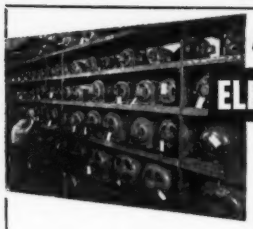

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Prompt guaranteed engineering work on your electrical power equipment by our staff of experienced engineers. Write today.

SQUIRREL CAGE MOTORS

H.P.	Make	Type	Volts	Speed
1250	Al. Ch.		2300/4000	3600
750	G.E.	56947		3600
		KF-	2300	1800
500	G.E.	KTP	440	1800
350	West.	CS	2200	900
250	G.E.	IK	2200	900
200	West.	CS	400	720
150	G.E.	TEFC	550	720
100	Al. Ch.	AR	440	514
100	Al. Ch.	AR-SB	2200	1200
75	G.E.	IK	440	720
75	Al. Ch.	AN	440	1200
60	Al. Ch.	AR	440	514
50	West.	CS	2200	900
30	G.E.	KT	440	900
25	Cr. Wh.	118Q	220	1200

SLIPRING MOTORS

3000	G.E.	IM	2200	120
1000	Al. Ch.	Any	2300	240
800	West.	CW	6600/440	507
750	G.E.	MT-16	2200	450
500	Ideal	AY	2200/4000	1800
400	Al. Ch.	ANY	4000	514
350	G.E.	IP	2300	720
300	Al. Ch.	ANY	2300	720
250	Cr. Wh.		440	600
125	G.E.	IM	2300	720
100	Al. Ch.	ANY	440	720
60	West.	CW	2300	870
30	Lincoln	Crane	440	900
15	Al. Ch.	ARY	440	900
11	West.	CW	440	1100
7½	G.E.	ITC	440	1200

SYNCHRONOUS MOTORS

2100	G.E.	ATI	4600	514
1000	West.		2300	900
800	Cr. Wh.		440	300
500	G.E.	TS	2200	900
430	E.M.		440	240
250	Al. Ch.		2300/4000	720
200	Al. Ch.	PF-100	2300	
			440	360
150	Cr. Wh.		220	720
145	G.E.	ATI	440	900
125	G.E.	TS	440	600
100	G.E.	ATB	2300	900
100	G.E.	ATI	2200	1800
75	G.E.	ATI	220	900
60	G.E.	TS	220	1200
20	Elwn-Wy	15-VRN	440	1200
15	Century		440	1200

D.C. MOTORS—110 VOLTS

H.P.	Make	Type	Speed
125	G.E.	RC-29A	500
55	G.E.	DLC-203A	1000
25	G.E.	RC-32	800
25	Cr. Wh.	CM-251	750
7½	Rel.	REB	1200
5	Sturv		570
5	G.E.	RC-7	1150
3	G.E.	HC-23B	3450
3	G.E.	B-224	3500
2	G.E.	CVC-111	1160
2	G.E.	RC-25	1150
2	G.E.		1400
2	G.E.	RC-22	3450
2	G.E.	RC	3450
1½	Diehl	C-305	460
1½	Watson	BW-3	550
1½	West.	SK-224	1150
1½	West.	CD	1725
1	Diehl	16	475
1	Elec.M.	E	2500

ADJUSTABLE SPEED D.C.—110 VOLT

H.P.	Make	Type	Speed
60	Sprague	C	500/1500
30	West.	E	615/1230
20	Roth		685/1165
10	G.E.	RC	575/1150
10	S.W.		600/1200
4½	Cr.Wh.	CM-1Q1F	580/1740
½	Roth		350/1400

ADJUSTABLE SPEED D.C.—230 VOLT

H.P.	Make	Type	Speed
500	G.E.	MFC	165/330
250	ELD		400/1200
180/230	G.E.	MPC	730/980
175/350	G.E.	MPC	400/800
100	D.C.	Dyn.	200/3500
75	West.	SK	350/450
50	G.E.	C	300/900
30	West.	SA	400/1200
30	G.E.	SP	240/700
30	Sprague	C-60	240/300
30	Tri.	JF	250/750
25	G.E.	RC-16	500/700
25	G.E.	DLC	600/1000
25	G.E.	RC	500/700
25	West.	S-9	560/780
15	G.E.	LC	550/1000
15	G.E.	RC-16	500/700
10	West.	SK-100	400/1600

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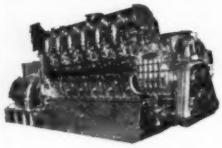

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1000 KW TO 100 KW

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HEMCO

1000 KW, 2400 Volts, 3 Phase, 60 Cycle, 720 RPM, General Motors and Fairbanks-Morse
750 KW, 2400 Volts, 3 Phase, 60 Cycle, 720 RPM, General Motors
300 KW, 450/2400 Volts, 3 Phase, 60 Cycle, 1200 RPM, General Motors
100 KW, AC or DC, 1200 RPM, General Motors
900 HP, General Motors, Propulsion Unit Complete
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IDAHO POWER COMPANY HYDRO-ELECTRIC EQUIPMENT *FOR SALE*

1. 2 S. Morgan Smith Hydraulic Turbines
Serial Nos. 8769 and 8770—200 rpm
Capacity 3240 bhp at 37' head eff. 82.5%
Manufactured 1935
Note: These are open pit turbines with horizontal shaft, 2 runners, marine type oil lubricated remote and middle bearings in excellent condition, after 13 years of continuous service.

2 Woodward Hydraulic Governors
Type LHR—Size 12½ x 16
30,000 foot lbs. Serial Nos. 6911 and 6912
Rotary pump and tank size 27 Nos. 6911-6912
Note: Excellent condition. These are the governors for above turbines.

2. 2 Westinghouse AC Generator
Serial Nos. 705530 & 935210
2000 Kva 6600 volt 175 amps
3 phase 60 cycles 200 rpm
250 volt exctation
Note: Have been in service 38 years, winding should be replaced for dependability. On hand at this time are one complete set of Type BRHVX stator coils with all necessary assembly insulation.
2 Westinghouse D.C. Generators
Serial No. 762312 & 762785
Volts 250 Amps 400 100 Kw
Speed 200 rpm
For direct connection to AC Gen.
Note: Direct connected exciters for above generators. One in first-class condition, the other requires repairs at armature.

3. 1 Westinghouse AC Generator
Serial No. 762760
5000 Kva 6600 volt 316 amp
3 phase 60 cycles 223 rpm
250 volt excitation
Note: Installed new in 1919, has been in service continuously for 29 years. Stator winding insulation not in best of condition, will require complete new coils and insulation for dependability in service.
Exciter belted to
Westinghouse Induction Motor
Type CS Style No. 160825A
Serial No. 2035484
3 phase 60 cycles Speed 1170
Volts 440 Amps 85 HP 75

4. 7 Westinghouse transformers
Spec. No. 76074 Kva 01WC
44000/6600 volts Indoor Bushings
Serial Nos. 224880-224890
224891-272828-272829
272840-272841
Note: Have given no trouble of any kind in 38 years of service indoor type water cooled.

5. 3 Westinghouse transformers
Spec. No. 126609 1,500 Kva 01WC
44000/6900 volts Outdoor Bushings
Serial Nos. 226478-226479-226480
Note: Transformers for generator item No. 3 in excellent condition.

MALAD EQUIPMENT NAMEPLATE DATA

6. 1 Allis Chalmers AC Generator
Serial No. 1080952 2500 Kva
3 phase 60 cycle 450 rpm
2300 volts 1380 amps
Note: Has been in service 37 years. Winding in very good condition. On hand one complete set of type A coils with necessary assembly insulation and 25% new laminations.
Direct connected exciter
Allis Chalmers DC generator
Serial 78062 50 Kw
120 volts 417 amp 450 rpm

7. 1 Allis Chalmers Hydraulic Turbine
Type M.H.E. Serial No. 255
7500 HP 125 Ft. Head 450 rpm
Horizontal Double Runner
Note: Horizontal type turbine in steel pressure box with thimble for penstock connection. Directly connected to generator Item No. 6. Runners are bronze.

BELLVUE EQUIPMENT

8. 2 S. Morgan Smith 30" McCormick hydraulic turbines, double runner, 36' head 300 rpm, 500 hp at 75 gate. Turbines mounted in ¼" plate steel cylindrical case 8' in diameter by 12'9" long. Case has 6'0" diameter inlet. (Manufactured in 1908.)
2 Westinghouse AC generators, 300 kw, 6600 volt, 26.3 amp., 300 rpm with 2-30 kw belt driven exciters.

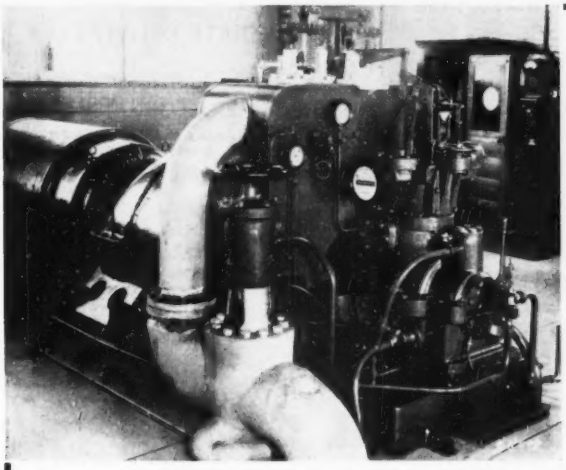
9. DC Switchboards with main switches and field breakers and Terrill regulators are available for above.

IDAHO POWER CO.

BOISE, IDAHO

TURBO-GENERATOR UNITS

RIGHT AND RELIABLE FOR YOUR PLANT



(Actual View of Installation)

AVAILABLE IMMEDIATE SHIPMENT

Westinghouse, 3600 RPM condensing steam turbo generator unit consisting of:

TURBINE

1500 KW, 250 P.S.I., 150° S. H. 28 inch vacuum direct connected to:

ALTERNATING CURRENT GENERATOR

1875 KVA, 1500 KW, 80% P.F. 3 phase 60 cycle, 2400 volt 451 Amp. complete and equipped with:

ACCESSORIES

2700 square foot Westinghouse surface condenser, condensing auxiliaries, piping, valves, duplicate exciter sets, switchboard panels and instruments.

EXCELLENT CONDITION

TURBINE-GENERATOR UNITS

3 PHASE, 60 CYCLE

6250 KVA G.E. condensing, 5 stage, 2300/4000 volts, 200# pressure, 600°TT, 3600 RPM, complete with exciter, switchboard and surface condenser.

1 New 5000 KVA G.E. non-condensing Automatic Extraction, 3 phase, 60 cycle, 13,800 volts W.Y.E. 600# P.S.I., 750°TT 150# extraction and 25# gauge back pressure.

3125 KVA G.E. condensing 175/200 psi, 2300 volt, 500°TT, 3600 RPM, complete exciter, switchboard, and condenser.

1563 KVA G.E. condensing 300 to 400 lbs. pressure, 2300 volts, 3600 RPM, complete exciter, surface condenser.

625 KVA Westinghouse condensing, 150/200# pressure, 2300 volt, 3600 RPM, complete exciter, switchboard, surface condenser.

625 KVA G.E. condensing, 150/175# pressure, 480/2300 volts, 3600 RPM complete exciter, switchboard, surface condenser.

625 KVA G.E. non-condensing, 150# pressure, 15# back, 2300 volts, 3600 RPM complete exciter, panel.

375 KVA (4) G.E. condensing 400# pressure, 2300/4150 volts, each complete exciter, switchboard, surface condenser.

125 KVA G.E. non-condensing, 175 to 200 lbs. pressure, 10# gauge back, 2300 volts, 3600 RPM complete.

100 KVA Westg. non-condensing, 125 to 150 lbs. pressure, 10# gauge back, 2400 volts, 3600 RPM.

TURBINE-GENERATOR UNITS

DIRECT CURRENT

(2) 400 KW, 240 volts direct current Crocker-Wheeler Worthington 440 lbs. pressure condensing steam turbine-generator units.

(3) 200 KW New General Electric 200/250# pressure, 120 volts condensing turbine generator units.

(2) 150 KW 3-wire 250 volts 225/250 psi, Westinghouse-Worthington condensing turbine generator units.

75 KW Allis-Chalmers-Terry, 125 volts, 2400 RPM, 150 lbs. pressure non-condensing turbine generator unit.

(3) 60 KW new Westinghouse 120 volt, 200# pressure, condensing turbine generator units.

SURFACE CONDENSERS

1—New 8400 sq.ft. Ingersoll-Rand 2-pass Surface Condenser.

1—4400 sq.ft. Worthington Surface Condenser.

1—1250 sq.ft. Elliott Surface Condenser.

Utilities Electrical Machinery Corporation

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General Motors 900 HP Model 12-567, 2 cy. 12 cyl. 744 RPM with Falk reversing and reduction gear, ratio 2½ to 1. Electric starting. Auxiliaries available.

DIESEL GENERATORS

100 KW DC 240/120 V., 417 Amps., 1200 RPM. Motor: Superior, 150 HP Model GDB-8, 8 cyl., Electric Starting. Auxiliaries Available.

TURBO-GENERATORS

132 KW. AC, GENERAL ELECTRIC, Generator: 450 & 220 V, 3 Phase, 60 cycle, 1200 RPM. 275 Amps. Exciter: 40 KW. DC. 120 V. 22.6 Amps. Reduction Gear: 10071 to 1200 RPM. Turbine: 172 KW. Condensers available.

60 KW. DC. WESTINGHOUSE, Generator: 120 V. 1800 RPM. 500 Amps. Reduction Gear: 7283 to 1800 RPM. Turbine: 60 KW. 89.4 H.P. Condenser available.

NUMEROUS OTHER ITEMS ARE AVAILABLE FOR INDUSTRIAL USE.

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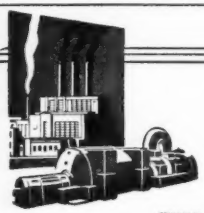

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Stewart of Cincinnati has stood for sound and intelligent handling of

HEAVY POWER EQUIPMENT

TURBO GENERATORS
(ISP: 125# 486° to 600# 750° FTT)

ITEM No.	QUANTITY & CAPACITY	
51	1250 KW	125# 486° ISP. 600 volt. CONDENSING. All auxiliaries. 1920.
62	300 KW	150# 486° ISP. 120-208 volt. CONDENSING. All auxiliaries. 1927. Factory rebuilt and rewound 1940.
432	500 KW	175# 486° ISP. 480 volt. EXTRACTION @ 15#G.
740	1000 KW	150# 486° ISP. 2400 volt. EXTRACTION: 38,600# /hr. @ 10#G. 1927.
18	1250 KW	200# 486° ISP. 2400 volt. CONDENSING. All auxiliaries. 1924.
1049	2000 KW	175# 486° ISP. 2400 volt. CONDENSING. All auxiliaries. 1918. Entirely overhauled and rebuilt 1940. In all critical and moving parts it shows 5 years' normal wear. Heavy 3rd stage wheel installed. Total log record 8 years.
1887	3000 KW	200# 486° ISP. 2400 volt. CONDENSING. All auxiliaries. 1919.
1544	1000 KW	250# 550° ISP. 2400 volt. NON-CONDENSING @ 50#G. 1935.
1638	1500 KW	250# 550° ISP. 2400 volt. CONDENSING. 1927.
601	2500 KW	250# 550° ISP. 2400 volt. EXTRACTION: 90,000# /hr. Max. @ 15#G. Built 1927. Good condition. Some spare blading.
60	(2) 1000 KW	150# 600° ISP. 480 volt. CONDENSING. All auxiliaries. 1929.
1625	1000 KW	250# 600° ISP. 2400 volt. CONDENSING. All auxiliaries. 1933.
603	2500 KW	250# 650° ISP. 2400 volt. CONDENSING. All auxiliaries. 1934.
1866	1250 KW	400# 650° ISP. 2400 volt. EXTRACTION @ 160#G. (Available with this is a 1000 KW, 160# ISP, 5#G. extraction machine.)
1473	4000 KW	600# 750° ISP. 13.8 KV. MAX. THROTTLE FLOW: 95,000# /hr. AUTOMATIC CONTROLLED EXTRACTION: 45,000# /hr. @ 125#G. (Can modify 125# to 150# and BACK PRESSURE @ 20#G (Can modify 15# to 25#). Minimum to exhaust @ max. extraction: 3000# /hr. Complete except switchgear. New—never installed.

TURBO ONLY

ITEM No.	QUANTITY & CAPACITY	
953	2000 KW	185# 500° ISP. Non-Condensing @ 40#G. 3600 RPM. 1935. Replaced by extraction machine. Rated 2000 KW maximum.

BOILERS

1864	700 HP	450# 600° FTT. C.E. Co. Chain grate stoker fired. All controls. 60,000# /hr. each.

TRANSFORMERS 1 PH.

794	(3) 2000 KVA	27 KV Primary. 2300 and 480. Rated 1500 KVA at 2300 and 5000 KVA @ 480.
1814	(2) 2000 KVA	33 KV (4-2½% taps above and below) Primary. 2300 Secondary. Less than one year service.

TRANSFORMERS 3 PH.

1856	2500 KVA	13.2 KV Primary. 6.6 KV Secondary (with two 10% taps below).
669	(7) 1000 KVA	11.5 KV Primary. 480 V Secondary. Pyranol filled.
1515	(5) 7500 KVA	33 KV Zig-Zag Primary. 13.8 KV Secondary (Reconnectable to 6.9 KV).

FURNACE TRANSFORMERS

345	4000 KVA	(1 ph) 24 KV (with 2-10% taps below) Primary. 228/92 (in 12 steps) Secondary Transformer 5%, Reactor 30% Reactance. Built 1942. Used 2 years.
1521	(6) 3000 KVA	(1 ph) 13.2 KV pri. 240/160 (6 taps) Secondary.
666	(3) 8000 KVA	(3 ph) 11 KV Primary. 100/160 Secondary.
673	1000 KVA	(3 ph) 7.2 KV (with 1-10% tap above and 2 below) Primary. 214/125/94 Secondary. 1934.
604	1200 KVA	(3 ph) 12 KV Pri. 190/87 (8 taps) Secondary. 1931.
350	300 KVA	(2 ph) 230 V. Primary. 120/60 Secondary. New.

MOTOR GENERATOR SETS

607	1000 KW	250 Volt D.C. 2400 volt A.C. 514 RPM.
641	300 KW	250 volt D.C. 2400 volt A.C. 1200 RPM. Rebuilt and guaranteed.
1415	200 KW	250 volt D.C. 480 volt A.C. 1200 RPM. Rebuilt and guaranteed.

ROTARIES

801	(2) 1500 KVA	275 volt D.C. 13.8 KV A.C.
816	2925/3705	222-285 volt D.C. 13.8 KV A.C. Syn. booster.

PAUL STEWART

UNION TRUST BUILDING • CINCINNATI, 2 OHIO

MAin 5873
MAin 3427

"SUCCESSFUL OPERATION GUARANTEED" *Belyea*

We Rebuild in accordance with N.I.S.A. Standards

D. C. MOTORS

Qu.	HP	Make	Type	Volts	Speed
1	2000	Whse.		600	600/720
1	1750	Whse.		600	550/700
2	1500	Whse.		525	600
1	1200	Whse.		600	525/700
1	700	G.E.	MCF	600	150/525
1	450	G.E.	MPC	250	115/145
1	600	Whse.		600	800/950
2	600	G.E.	MPC	600	600/720
1	335	Whse.	MQ	250	300/900
1	200/300	G.E.	MPC	220	360/920
1	275	Whse	QM-600.6	230	425/850
1	250	G.E.	MPC	230	400/500
1	220	Al. Ch		230	700
3	150	Whse.	SK-200	230	600
1	150	Cr. Wh.	CMC-65H	230	1150
1	150	G.E.	MPC	230	230/480
1	80	Cr. Wh.	152HL	230	300/1050
3	150	Cr. Wh.	TEFC-87H	230	890
1	150	G.E.	CD-B-Brg.	600	250/750
2	125	G.E.	CO	270	625
1	125	El. Dy	30S	230	750/1550
1	115	Cr. Wh.	JHL	230	1200
1	100	G.E.	CD-175	230	365/730
1	100	G.E.	MPC	230	225/450
3	100	Whse.	SK-Vert.	230	485/950
2	100	Rel.	1050T	230	400/1100
1	80	El. Dy.	30S	230	475/950
3	75	Cr. Wh.	53B-TEFC	230	860
1	75	Whse.	SK-180	125	650
3	75	G.E.	CDM-1126Y	230	2000

TURBO GENERATOR SETS

See ad on page 581

SYNCHRONOUS CONDENSERS

Qu	KVA	Make	Type	Volts	Speed
1	5140	Wh.e.	TSC	2400/4150	900
1	4000	G.E.		2400	900
1	3000	Whse.		2400	720

MOTOR GENERATOR SETS

3 Ph. 60 Cycle

Qu.	KW	Make	Speed	DC Volts	AC Volts
1	2000(30)	Whse.	720	600	2300
1	1500	G.E.	360	275	2200/4400
1	1500	G.E.	600	600	4150
1	1500	Whse.	600	600	4150
1	1250	G.E.	600	275	2300/4150
1	1000	Cr. Wh	720	250	2300/4150
1	1000	Whse.	514	250	4000
1	1000	Whse.	720	600	2300/4150
1	1000	Whse.	900	600	2300/4150
1	800	SUGE	1200	240	2300
1	500	G.E.	720	125	2300/4150
1	500	G.E.	720	600	4400
1	750	Whse.	720	275	2300/4150
1	400	G.E.	720	250	440/2300
1	400	G.E.	1200	120/240	440
1	350	G.E.	900	125	4150
1	300	G.E.	1200	120/240	440
1	250	Whse.	1200	240	440
1	150	Cr. Wh.	1200	250	220/440
1	140	Cr. Wh.	720	125/250	2200

ROTARY CONVERTERS (60 cycle)

Qu.	KW	Make	Speed	DC Volts	AC Volts
1	2000	G.E	514	600	13200
1	2000	G.E	450	600	13200
1	1000	Whse.	900	600	11000
1	750	Whse.	900	600	13200
1	500	Whse.	900	250	6600

All units can be furnished with AC and DC Control

MERCURY ARC RECTIFIERS

1	1000	Al. Chal.	B-612	625	13500
*1	1000	B-B	25/60 cy.	625	6600/13200
1	750	G.E.	RHW	575	2300/4000

*Complete with full automatic A.C. and D.C. controls.

A. C. MOTORS—3 Ph. 60 Cycle

Synchronous

Qu.	HP	Make	Type	Volts	Speed
2	2500	G.E.	TS	2300	257
1	2100	G.E.	ATI	4800	514
2	2000	Whse.		2200	120
1	1470	Whse.		2300/4600	900
1	1000	Whse.	MILL	2300	189.5
2	900	Al. Ch	Eng. (new)	2200	150
1	600	Whse.		440	360
1	500	G.E.	ATI	4160	900
2	500	G.E.	TS-9832	4160	600
1	450	Whse.		2200	128.5
2	350	G.E.	TS	2200	180
1	320	G.E.	ATI	2300	600
1	308	Al. Ch.		440	600
1	300	G.E.	ATI	440	720
1	300	Whse.	Elec.	2300	720

Slip Ring

1	1000	Whse.	CW	2300	705
2	700	Whse.	CW	2200	900
1	600	G.E.	MT	440	720
1	500	G.E.	IP	550	505
3	450	G.E.	IM	440	505
1	500	G.E.	Mill-IM	2200	450
3	350	Whse.	CW	2200	900
1	350	G.E.	MT-442y	4000/23	257
1	300	Al. Ch.	ANY	2300	505
3	300	Al. Ch.	ANY	2300	705
1	250	G.E.	MT	4000	257
1	250	G.E.	MT-559S	2200	750
1	135	G.E.	IM	2300	705
4	125	G.E.	MT-566Y	2300	435

Squirrel Cage

1	250	G.E.	KT-55C	440	1780
1	200	G.E.	KT-557	440	1800
1	200	G.E.	IK	550	885
1	150/50	Whse.	CS	440	720/1443
1	125 (new)	G.E.	KF TEFC	440	1190
1	125	G.E.	KF-6328L	440	3558
2	100	G.E.	KT-543	220/440	1780

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AVAILABLE IN STOCK

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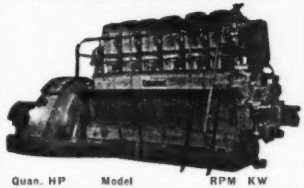

Quan.	HP	Model	RPM	KW	
*2	450	Enterprise DSG-6	450	300	AC
*2	450	Enterprise DSG-6	450	300	DC
2	1600	General Motors 16-278-A	720	1250	AC
2	150	General Motors 3268A	1200	100	DC
1	385	Ingersoll Rand "S"	600	250	DC
*2	240	Buckeye 80	600	160	AC
*2	90	General Motors 6043-C	1200	60	AC
*2	90	General Motors 6-71	1200	60	DC

*—new.

DIESEL MOTORS CORP.
Port Washington, N. Y.
Port Washington 7-2000

DIESEL GENERATOR UNITS

IN STOCK—IMMEDIATE SHIPMENT

2—1420 KVA—FAIRBANKS MORSE—NEW ALTERNATORS DIRECT CONNECTED TO FAIRBANKS MORSE MODEL 38D8-1/8 1600 HP—720 RPM—DIESEL ENGINES.

2—1250 KVA—CROCKER WHEELER—NEW ALTERNATORS DIRECT CONNECTED TO FAIRBANKS MORSE MODEL 38D8-1/8 1600 HP—720 RPM—DIESEL ENGINES.

2— 620 KW—240 VOLT—DC GENERAL ELECTRIC GENERATORS DIRECT CONNECTED TO ALCO TYPE 6—12½ X 13-T 900 HP—700 RPM DIESEL ENGINES.

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25 cy. 60 cy. D.C.

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Solenoid Operated Oil Circuit Breakers
6—1200 amp at 60 cycles, 750,000 KV Interrupting Capacity
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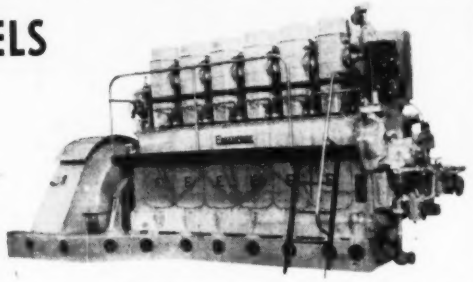

OTHER DIESELS AVAILABLE
UNIT CAPACITIES—10 TO 1420 KVA
A.C.—50 AND 60 CYCLES

A PARTIAL LIST OF OUR INVENTORY

KVA	Make	Model	HP	RPM	KVA	Make	Model	HP	RPM
1420	Fairbanks Morse	38D8⅛	1600	720	312	General Motors	8-268A	450	1200
1250	General Motors	16-278A	1600	720	300	Fairbanks Morse	YVA	360	257
900	General Motors	12-567	1080	720	200	Buckeye	80	240	600
625	Superior	OS	750	327	125	General Motors	3-268A	150	1200
425	Baldwin	VO-6	510	450	75	General Motors	6016-E	90	1200
375	Enterprise	DSG-6	450	450	62	Int'l Harvester	UD-18	76	1200

WRITE FOR COMPLETE INFORMATION

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TRANSFORMERS

60 CYCLE — 1 PHASE

3—25 KVA Niagara O.I.S.C. 2400/4160Y-120/240.
3—25 KVA Niagara O.I.S.C. 2400/4160Y-240/480.
3—37½ KVA Niagara O.I.S.C. 2400/4160Y-120 240.
3—37½ KVA Niagara O.I.S.C. 2400/4160Y-240/480.
3—50 KVA Niagara O.I.S.C. 2400/4160Y-120/240.
3—50 KVA Niagara O.I.S.C. 2400/4160Y-240/480.
3—75 KVA Niagara O.I.S.C. 2400/4160Y-120/240.
3—75 KVA Niagara O.I.S.C. 2400/4160Y-240/480.
3—100 KVA Niagara O.I.S.C. 2400/4160Y-120 240.
3—100 KVA Niagara O.I.S.C. 2400/4160Y-240/480.
3—150 KVA Niagara O.I.S.C. 2400/4160Y-240/480.
3—200 KVA Niagara O.I.S.C. 2400/4160Y-240/480.
3—250 KVA Niagara O.I.S.C. 2400/4160Y-240/480.
3—333 KVA Niagara O.I.S.C. 2400/4160Y-240/480.

All transformers listed for May Stock List—Short delivery on sizes from 25 KVA to 5000 KVA, 1 or 3 phase in voltage ratings to 40 KV.

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ERIE ELECTRIC CO., INC.
118 CHURCH ST. Phone: CL. 4758 BUFFALO 2, N. Y.

1—300 KW 3ph. 60cy. 2300V G.E. Generator 1200 RPM connected to one GE 500 RPM non-cond. Turbine through reduction gear. Complete with switchboard water rate 33#.
2—G.E. Generators 300 KW 600 V D.C. 1200 RPM connected to one G.E. 500 RPM non cond. Turbine through reduction gear. Complete with switchboard.
All three units loaded on cars for $7,500.
All Equipment 1932.
1—481 HP Springfield Sectional Header Boiler with super heat. 225# 1927.
2—200 HP B&W Sectional Header Boilers 200#.

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TRANSFORMERS

169 Moloney Transformers. 1.5 to 150 KVA. single phase. 60 cycle. 120/240/7620/13200Y. 5—2½% taps. used only three years.

BOILERS

2—605 HP and 1—505 HP Wickes 3-drum low head water tube boilers. Various other boilers. Contact

GREEN & REEDY
Phone 10-J Franklinton, Louisiana

3—G.E. 1 PHASE SELF COOLED

TRANSFORMERS

Rated—1667 Kva 66000—19100/33,000 Y volts 55 Deg. C Rise Impedance 7.83%. Total weight 27000 lbs. Taps on high voltage side for 66000, 62700, 59400, 56100, 52800 volts with external tap changer. Serial Nos. 2871230, 2871231, 2871232.

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Purchasing Department
HAGERSTOWN, MARYLAND

"BREW, WOLTMAN OFFERS"

SUB STATION EQUIPMENT

TRANSFORMERS — 60 Cy.

1—2000 KVA G. E.	66000—13800/23900 Y 3 ph.
3— 500 KVA G. E.	66000—13200/6600 V.
3—2000 KVA West.	66000—11000 V.
3—1000 KVA West.	66000—11000 V.
1—2500 KVA G. E.	34500—4330 V. 3 ph.
4—7500 KVA Al. Ch.	33000—13800 V. 3 ph.
3— 667 KVA Pitts.	33000—11000 V.
3— 250 KVA West.	33000/11000—6600 V.
6— 50 KVA G. E.	33000—2300 V.
6— 75 KVA Moloney	33000—2300/6900 V.
3—3750 KVA West.	26400/13200—2400 V.
4— 450 KVA Al. Ch.	25410/44000—13280/23000 Y
3—1667 KVA Wagner	23000—575 2300 V. 25 cy.
2—1000 KVA G. E.	22000/11000—2300/4000 Y
3— 250 KVA West.	22000—2300/4150 V.
3— 50 KVA West.	22000—2300 V.
2—4000 KVA Penn. Furn.	22000—228 V. 3 ph.
3— 100 KVA G. E.	13200—2200 V.
2— 750 KVA G. E.	13200—480 V. 3 ph.
6—3000 KVA Al. Ch. Furn.	13200—200 V.
2— 200 KVA G. E.	11500—220/110 V.
3— 200 KVA Moloney	11000—2300 V.
3— 167 KVA G. E.	7200/12400 Y—240/480 V.
1—1500 KVA West. Auto	4000—2300 V. 3 ph.
1— 100 KVA G. E.	2300—575 V. 3 ph.

TRANSFORMERS—Contd.

3—250 KVA Al. Ch.	2300—460 V.
3— 20 KVA West.	2200—575/287½ V.
3—7½ KVA G. E.	600—120/240 V.
12—15 KVA Standard	450—117 Delta
2—27½ KVA G. E.	440—220/110 V.

FREQUENCY CHANGERS

1—12500 KVA G. E. 25/60 cy. 300 RPM
2— 3000 KVA West. 25/60 cy. 300 RPM
1— 2500 KVA G. E. 25/60 cy. 300 RPM
2— 1000 KVA G. E. 25/60 cy. 300 RPM
1— 500 KVA Al.Ch. 25/60 cy. 300 RPM

OIL CIRCUIT BREAKERS *Outdoor*

2— 800 A. 87 KV Am. Brown Boy.
1— 600 A. 73 KV G. E. FHKO-139
1— 400 A. 73 KV G. E. FKO-136
1— 400 A. 73 KV G. E. FHKO-236
3— 400 A. 37 KV West. G-11
4— 400 A. 37 KV G. E. FKO-136
1—1200 A. 25 KV G. E. FHKO-236
1— 400 A. 25 KV G. E. FKO-136
2—1000 A. 23 KV Kelman CB-76
4— 600 A. 15 KV G. E. FHKO-139BS

MOTOR GENERATOR SETS

2—1000 KW Gen. Elec. 600 V. DC 60 cy.
1— 500 KW Gen. Elec. 250 V. DC 60 cy.
1— 200 KW Gen. Elec. 60 V. DC 60 cy.
1— 75 KW Star 240 V. DC 60 cy.
1— 75 KW Ridgway 115 V. DC 60 cy.
1— 75 KW West. 125 V. DC 60 cy.
1— 18 KW West. 60 V. DC 60 cy.

ROTARIES—60 Cy.

1—2929/3705 KW Gen. Elec. 225/285 V.
1—2025/2565 KW Gen. Elec. 225/285 V.
2—1500 KW Westinghouse 270 V.
1— 500 KW Westinghouse 250 V.
2— 165 KW General Electric 250 V. 3 Wire.

MERCURY ARC RECTIFIERS

2—4500 KW Ignitron 600 V. DC
2—3250 KW Ignitron 650 V. DC
1—1850 KW Ignitron 275 V. DC

VOLTAGE REGULATORS

1—600 KVA 200 A. 4160 V. Gen. Elec. 3 ph
3—130 KVA 96 A. 13200 V. Gen. Elec.
1— 72 KVA 300 A. 2300 V. Gen. Elec.
3— 57½ KVA 250 A. 2300 V. Gen. Elec.
3— 46 KVA 200/400 A. 2300 V. West.
4— 36 KVA 150 A. 2400 V. Gen. Elec.
6— 24 KVA 100 A. 2400 V. Gen. Elec.
5— 12 KVA 50 A. 2400 V. Gen. Elec.

The items listed above are only part of what we have available. Besides having other items in the same classifications our full line includes:

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MOTORS SQ. CAGE

1—450 HP.—Ridgeway 900 rpm 2200v.
125 HP. G.E., 1800 rpm 2300v.
1—100 HP. Whse, 1800 rpm 440v.
1—100 HP. Whse, 1200 rpm 2200-440v.
1— 75 HP. Whse, CS, 1200 rpm, 2200 volts, 3 phase, 60 cycle.
1— 75 HP. 1800 rpm Westinghouse, 440 volt.
1—75 HP. General Electric Type KT 900 RPM 440 volt.
2—40 HP. G.E., 900 rpm 220v.
40/20 HP Westinghouse 800/450 44 volt

MOTORS SLIP RING

1—2500 HP G.E. MT 257 RPM 6600 volt
2— 150 HP G.E. Type IM 450 RPM 440 volt.
1— 100 HP G.E. Type IM 400 RPM 440 volt.
1— 100 HP G.E. 720 rpm 440v, 25 cy. IM.
75 HP. G.E. 1200 rpm 220v, 60 cy. Vert.
60 HP. West. 900 rpm 2200v, 60 cy. Vert.
50 HP. F.&M. 1800 rpm 220v. 60 cy.

MOTORS—D. C. 230 VOLTS

1—125 HP. G.E. 1800 rpm R.C.
1— 75 HP. 885 rpm General Electric
1— 50 HP. 700 rpm Crocker-Wheeler.

VARIABLE SPEED—220 VOLTS

1—35 HP. 300/1200 rpm Westinghouse.
1—30 HP. 440/1200 rpm General Electric.
2—25 HP. 650/2200 rpm Westinghouse.
2—25 HP. 300/900 rpm Electric Dynamic.
1—55 HP. 500/1500 rpm General Electric.

MOTOR GEN. SETS

1—1000 KW Westinghouse 275 volt, 720 RPM 4000 volt Syn.
1—1000 KW General Electric 600 volt 514 RPM 4000 Volt Syn.
1—500 KW. G.E. 250v 900 rpm 2300v Syn.
1—500 KW. G.E. 575v 900 rpm 2300v Syn.
1—125 KW. Crocker Wheeler 1200 rpm 125v Generator 2200v S.C. Motor.
1—100 KW. Elect. Mach. 1200 rpm 125v Generator 4150 Syn. Motor.

PLATING GENERATORS

1—1¼ KW. G.E. 5/6v with sq. cage mt.
1—12 KW. Hansen Van Winkle 24v 1200 rpm. 20 HP. General Electric KF Motor.
1—3000 Amp. Chandeysson, 6/12v 400 rpm Syn. Motor.
1—2500 Amp. ditto.
1—635 KVA West. Reduction Gear Turbo Generator Non-Condensing, 2400v 3 ph 60 cy.

TRANSFORMERS

1—1000 KVA G.E. 3 ph. 4150 volt to 2400 volt.
3—400 KVA. G. E. 6900 V. Pri.—2300 V. Sec.
3—300 KVA Pitts. 2300v pri. 115/230v sec.
3—200 KVA G.E. type H 2300v pri. 115/220v sec.
3—150 KVA West. 2300 volt Pri. 240/480 sec.
1—150 KVA G.E. 2300v 110-220v.
3—100 KVA G.E. 4150 v 240/480 v Pyranol.
3—100 KVA G.E. 4150 v 250/460 v Pyranol
3—75 KVA Amer. 2400v. pri. 240/480 sec.
6—50 KVA West. 2300 v. 120/240 v. Inerteen

ALTERNATORS & SYNCH. MOTORS

1—2500 KVA Westinghouse, Syn. condenser, 720 rpm 2200v with D.C. exciter.
1—320 KVA Allis Chalmers, 450 rpm 480v.
1—240 KVA General Electric ATB, 600 rpm 240v with D.C. exciter.
1—225 KVA 514 rpm 600v Westinghouse.
4—200/100 HP. Whse. 720/360 rpm 4150v.
1—200 HP General Electric 257 RPM 440 volt.
1—100 HP. G.E. type TS 600 rpm 4400v D.C.
2—150 HP. Allis Chalmers, 360 RPM, 2200 volt

Complete Line of A.C. and D.C. Motors and Generators

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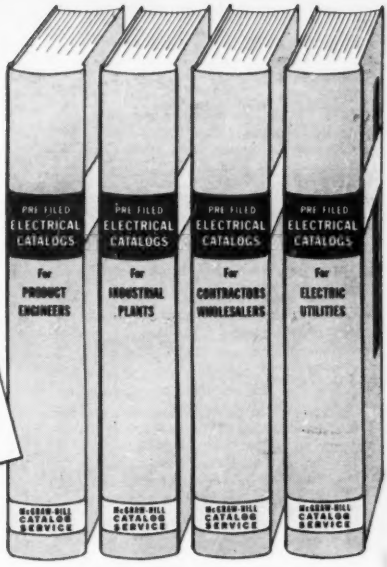

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KEEPING IN STEP WITH THE "Great Growth" INDUSTRY . . .

1 The first I-T-E Circuit Breaker

overcame "overfusing" and eliminated the one "hot" side that always remained after a circuit had been "protected" by a fuse.

Individually Enclosed Breakers
1922

The complete enclosure of air circuit breakers in steel appeared with the advent of individually motor-driven machines. In addition to the protective steel case, certain motor protective characteristics were introduced in the new product which was called "U-RE-LITE."

2 Inverse Time Element
1904

The addition of an oil-film time-delay dashpot made the circuit breaker a practical device. Time delay prevented a breaker from opening every time a motor started or a slight overload of short duration was imposed on the circuit.

For 60 years, I-T-E has set the pace for protection in electrified industry.

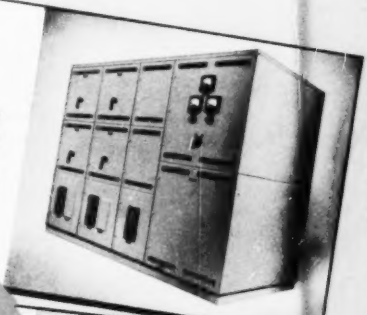
The story of I-T-E in many ways reflects the history of the Electrical Industry. While industrial electrification was still in its infancy, the need for more efficient electrical protection became apparent. I-T-E has been the center of switchgear progress ever since the early growth of power in industry demanded the use of adequate protection for electrical equipment. And today, I-T-E is still leading the way with more efficient, more dependable switchgear for industry.

Milestones along the path of I-T-E switchgear development present themselves as might an old-timer's review of a lifetime of electrical experience in any industrial plant or central station.

3

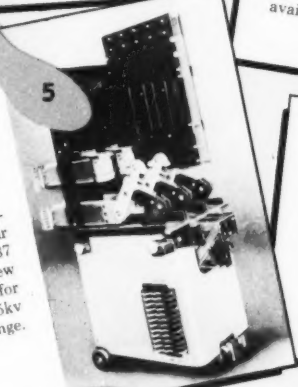
4 Metal-Enclosed Switchboards
1926

Demand for safety and compactness led to an I-T-E switchboard structure which completely enclosed in steel all circuit breakers and related bus. This structure was the first single-unit, completely factory-built, metal enclosed switchboard available to industry.



Air-Power Circuit Breakers
1938

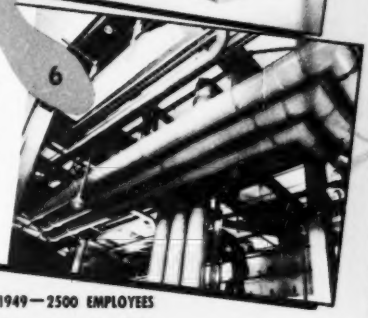
The successful installation of I-T-E 5kv air circuit breakers in 1937 opened up a whole new field of applications for air breakers in the 5kv to 15kv voltage range.



5

Isolated Phase Bus
1936

Developed to extend the high degree of isolation achieved in modern metal-clad switchgear to that portion of the electrical system between station generator-terminals and generator transformers. I-T-E and its present subsidiary R&IE pioneered the manufacture and sale of this equipment.



6

PRODUCTION KEEPS PACE TOO! 1900—50 EMPLOYEES, 1949—2500 EMPLOYEES

I-T-E has not only kept pace with the technological requirements of the electrical industry, but has also led the way in producing to meet the industry's demands. At the turn of the century it took but a handful of men to satisfy the market for circuit breakers. Today, over 2500 persons are employed in the production of I-T-E Switchgear, Unit Substations, Isolated Phase Bus Structures, Circuit Breakers, and related products.

R&IE

I-T-E CIRCUIT BREAKER COMPANY

19TH AND HAMILTON STREETS, PHILADELPHIA 30, PA.

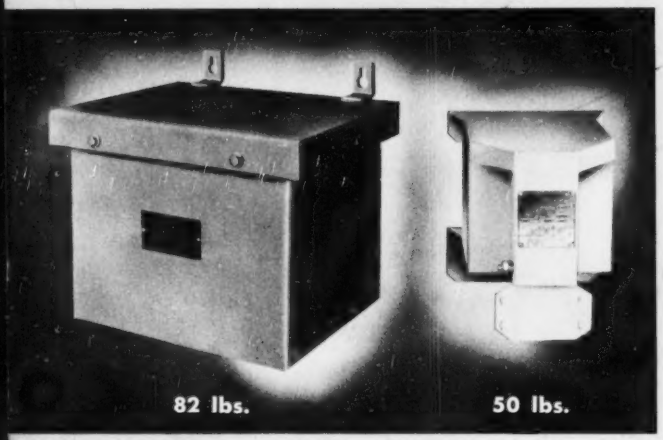
31 Offices in United States • In Canada, EASTERN POWER DEVICES, Ltd., TORONTO
Switchgear • Unit Substations • Isolated Phase Bus Structures • Circuit Breakers
Mechanical Rectifiers • Resistors • Special Products
For Power Switching Equipment, refer to Railway and Industrial Engineering Co., an I-T-E Organization

KUHLMAN AND TRANSFORMERS

—THEY GREW UP TOGETHER

Kuhlman's new trademark, reproduced here for the first time, is not patterned after Faraday's 1831 experimental model by accident.

Kuhlman's roots are deep in the transformer industry. Almost simultaneously with the first transformer installation by William Stanley at Great Barrington, Massachusetts, the Kuhlman Electric Company was founded. During the nearly six decades since then, Kuhlman has pioneered many outstanding transformer developments.



← Kuhlman was the first to oil impregnate transformer coil . . . the first to use varnish in place of compound impre nation materials in small distribution transformers. Kuh man also developed the forerunner of the present da series-multiple transformer. And Kuhlman clamp typ bushings eliminated the use of tools in making primar connections, thereby contributing greatly to the ease a safety of this important job.

On October 31, 1933, Kuhlman secured the patent on th now famous Bent Iron Core, a design that is today followe in different methods by all progressive transformer manu facturers. This core permits the use of oriented steel, wit resultant reduction in weights, core loss, copper los exciting current and impedance.

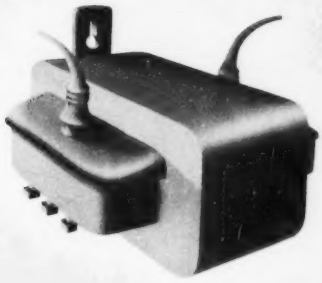
Kuhlman built transformers using the Bent Iron Core a early as 1934, and when, on September 23, 1938, Kuhlma began using cold rolled steel in core construction became one of the first to take this important step.

The photograph illustrates what is perhaps Kuhlman' newest contribution to the transformer industry. It is dramatic example of how Silicone insulation combine with the Bent Iron Core saves approximately 35% i weight and provides 15% more overload capacity in a KVA distribution transformer, manufactured by Kuhlma for the Bureau of Ships, United States Navy.

SILICONES MAY REVOLUTIONIZE TRANSFORMER OF THE FUTURE

The distribution transformer of the future may look like this. The → extreme moisture resistance of silicone insulation would permit elimination of tanks and oil in distribution transformers for outdoor service. Without oil, bushings could be placed at the bottom where they would be more easily accessible. Transformer size and weight would be greatly reduced. The exceptional heat stability of silicone would permit unheard of overload capacities.

Right now forward looking Kuhlman engineers are hard at work to make these dreams a reality. And so, Kuhlman continues to make transformer history . . . a great past points to an even greater future.



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